(12)

ASD-TR 81-5018

AD A125548

MANPOWER FORECASTS AND PLANNED MAINTENANCE PERSONNEL SKILL LEVEL CHANGES

Lawrence D. Howell, Major, USAF
Engineering Specialities Division
Directorate of Equipment Engineering

August 1980

DTIC
MAR 9 1983
H

TECHNICAL REPORT ASD/TR 81-5018

Final Report for Period 1 April 1979 - 1 June 1980

Approved for public release; distribution unlimited

DEPUTY FOR ENGINEERING
AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE

83 03 09 008

DTIC FILE COPY

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

Lawrence D Howell

LAWRENCE D. HOWELL, Major, USAF
Project Engineer

FOR THE COMMANDER

Claire J Evans

CLAIRE J. EVANS, Lt Col, USAF
Director, Equipment Engineering

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: ASD-TR-81-5018
2. GOVT ACCESSION NO.: AD-A125548
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): Manpower Forecasts and Planned Maintenance Personnel Skill Level Changes
5. TYPE OF REPORT & PERIOD COVERED: Final
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): Lawrence D. Howell, Major, USAF
8. CONTRACT OR GRANT NUMBER(s):
9. PERFORMING ORGANIZATION NAME AND ADDRESS:
Directorate of Equipment Engineering (ASD/ENESA)
Aeronautical Systems Division (AFSC)
Wright-Patterson AFB, Ohio 45433
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Project AFSD0161
11. CONTROLLING OFFICE NAME AND ADDRESS:
Directorate of Equipment Engineering (ASD/ENEZ)
Aeronautical Systems Division (AFSC)
Wright-Patterson Air Force Base, Ohio 45433
12. REPORT DATE: August 1980
13. NUMBER OF PAGES:
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
15. SECURITY CLASS. (of this report): Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (of this Report):
Approved for public release; distribution unlimited.
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report):
18. SUPPLEMENTARY NOTES:
This report was also submitted as a dissertation to the Ohio State University Department of Industrial and Systems Engineering as partial fullfillment of the requirement for the degree Doctorate of Philosophy.
19. KEY WORDS (Continue on reverse side if necessary and identify by block number):

LCOM	Manpower Forcasts	Task Times
Maintenance Productivity	Maintenance Task Times	Sortie Generation
Maintenance Skill Level	Skill Level Efforts	Aircraft Manpower
Manpower Productivity	Productivity	Aircraft Maintenance
Skill Level		Aircraft Maintenance Productivity.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number):
See Reverse

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Block 20. (Cont.)

The purpose of this research effort was to establish a method to estimate the effect of reducing maintenance personnel experience levels. The performance measures of interest were sortie/mission generation capability and manpower required. The United States Air Force maintenance data collection system to obtain failure rates, interviews with maintenance experts to determine estimated task times for normal and low skilled maintenance personnel, and the Logistics Composite Model to computer simulate the maintenance organization, are the tools which were utilized in this research study to develop such a method.

Through this modeling technique productivity comparisons are made between normal (skill level 5) and low (skill level 3) maintenance personnel. A computer simulation model of the F-4E aircraft is used with maintenance task time for normal and low skill maintenance personnel.

When unlimited manpower is available, the maximum sortie generation capability of the simulation model utilizing all skill level 3 task times is approximately 75 percent of the maximum sortie rate of the mode utilizing all skill level 5 task times.

When manpower is limited to the minimum level capable of producing a particular percent of this maximum, the model utilizing skill level 3 task times requires 30 percent additional manning to accomplish 75 percent as many sorties in a given time period when changing from skill level 5 task times to skill level 3 task times.

A sampling technique is developed to acquire the inputs to the computer simulation which results in the same accomplishments as the previous technique. In addition, expected output is determined as the percent of maintenance personnel that possess each skill is varied.

DTIC COPY INSPECTED 2

Accession For
NTIS GRA&I
DTIC TAB
Unannounced
Justification
By
Distribution/
Availability Codes
Avail and/or
Dist Special

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

GLOSSARY OF TERMS

AFR	Air Force Regulation
DSARC	Defense Systems Acquisition Review Council
Hit Matrix	An analysis tool in LCOM that gives the number of times during a simulation that any particular task or malfunction occurred.
LCOM	Logistics Composite Model. A large scale discrete state digital computer simulation framework to analyze number of aircraft, personnel, spare parts, and support equipment.
MDC	Maintenance Data Collection. A system whereby aircraft maintenance data is collected and maintained.
MMHPFH	Maintenance Manhours Per Flying Hour. The number of manhours of maintenance required for each hour that an aircraft flies.
POMO	Production Oriented Maintenance Organization.
PSR	Performance Summary Report
Skill Level	A number which relates to the experience or job knowledge of Air Force personnel.
Sortie	One aircraft flight as defined to include one take off and one full stop landing.
TAC	Tactical Air Command
Task Time	The elapsed time for a particular element of work to be accomplished.

TMULT	A term used in LCOM to describe the process of multiplying every task time by a given factor. TMULT is particularly useful in sensitivity analysis.
Work Center	A career field or set of related career field that make up a work group that have responsibility for particular maintenance of an aircraft weapon system.
WUC	Work Unit Code. An alpha numeric symbol that represents a particular system, subsystem, or elemental part on an aircraft.
Constrained LCOM Model	An LCOM simulation model (run) that has a limited number of personnel in designated work centers.

CHAPTER I

INTRODUCTION

Background and Research Problem

Approximately 60 percent of the total defense budget in the United States goes to pay for defense manning.[1] Some 35 percent of the defense manning is comprised of aircraft maintenance personnel. Therefore, reduction in the costs of aircraft maintenance personnel can greatly impact the overall defense manning costs.

The Air Force is also concerned with the recruitment of sufficient numbers of people to maintain the enlisted force. The Air Force is currently having difficulty recruiting enough educated young people to maintain present levels of manning.[2]

In order to reduce costs, there is much current emphasis upon shifting wartime requirements to the reserve forces.[3] Studies are currently underway to determine to what extent this can be done without adversely affecting the capabilities of the Air Force. However, the reserve units are also experiencing recruiting problems, and a temporary solution to the manning shortage must be found.

One possibility is to reduce the term of enlistment from the current four years to two years. This would have the following assumed benefits:

1. Entice more young volunteers into service.
2. Reduce the average pay scale of servicemen.
3. Make more trained personnel available to the reserves.
4. Allow more rapid utilization of new trainees.

Some of the arguments against a reduction in enlistment time include:

1. Increase training costs since enlisted members would have to be replaced sooner.
2. Increase manning requirements since experienced personnel are more productive.
3. Decrease mission accomplishments since lower skilled personnel will take longer to prepare and repair aircraft.

In connection with the problem, it has recently been requested that current methods of maintenance manpower forecasting be altered to allow for effective tradeoffs among personnel skill levels.[4] This forecasting is most applicable to developmental weapon systems that must be approved through the Defense Systems Acquisition Review Council (DSARC).

The Air Force recognizes that there are three specific requirements which enlisted personnel must satisfy to qualify for skill level upgrading. These requirements are: (1) career knowledge, (2) job proficiency, and (3) job experience.[5]

Skill levels are generally defined as follows:

1. 1-level - entry level, unqualified.

2. 3-level - graduate of basic technical training or initial on-the-job training, usually less than two years experience.

3. 5-level - fully proficient and capable of unassisted performance, usually 1-7 years experience.

4. 7-level - fully proficient and capable of supervising others, usually 5-15 years experience.

5. 9-level - supervisor or management level skills and knowledge, usually 10 years experience or more.

Requirements for skill level advancements come from Air Force Regulations (AFR 26-11, AFR 50-23, AFR 39-23, AFR 39-1, and AFR 35-1). See Figure 1 for the skill level advancement diagram reproduced from AFR 50-23.

At present, maintenance manpower authorizations for current and developmental aircraft weapon systems are based upon an "average" maintenance skill (5-level). Thus the research question is, "what effect upon mission accomplishment results from a reduction of aircraft maintenance personnel skill levels?" In planning for manpower skill level contingencies, management would like to know the impact upon mission accomplishment of the average

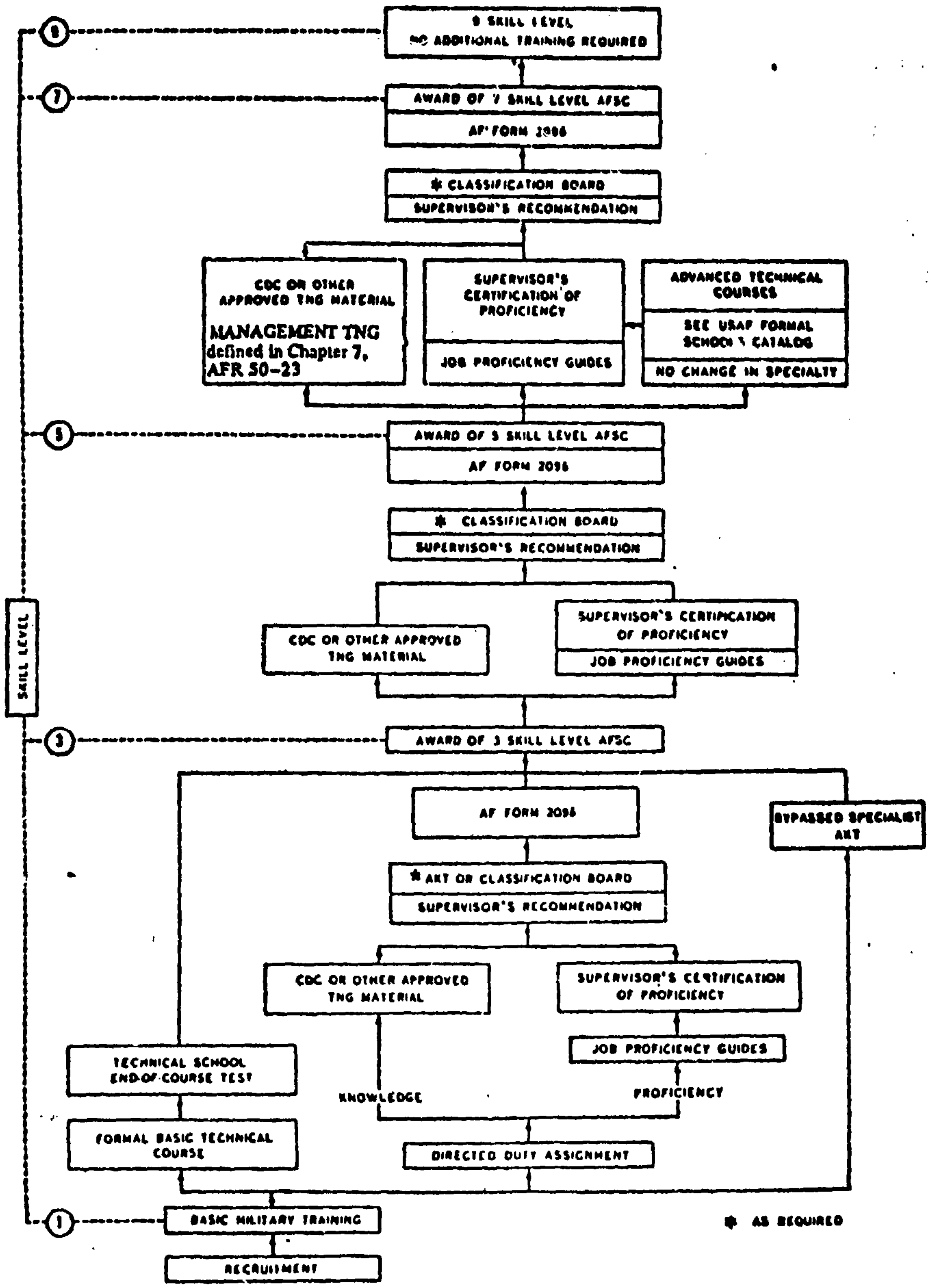


Figure 1. Skill Level Advancement Diagram

maintenance person possessing a 3-level proficiency.

At present, no method exists within the military to assess the impact of manpower skill level or proficiency changes. The primary purpose of this project will be to establish such a methodology. If the methodology established by this project proves valuable to the Air Force within the current framework, it can then be generalized to other services and industry.

Related Studies

One of the problems pointed out by the Comptroller General of the United States in a report to the Senate Committee on Appropriations is a weakness in the manpower requirements system.[6] This report points out that the military services operate nearly 25,000 aircraft with an annual maintenance cost of over 6 billion dollars. Military maintenance manpower is the largest recurring part of this cost. Sixty percent of defense spending is for manpower.

The military services are continually developing and adjusting manpower requirements. Each major command of the Air Force is charged with determining its aircraft maintenance personnel requirements. Most of these commands now use a highly sophisticated, computer-based system that simulates manpower requirements based on selected input criteria. This simulation system uses a preplanned framework or format called the Logistics Composite Model (LCOM).

This framework or language is then used as the basis around which a simulation model for a given aircraft organization is designed. The LCOM technique is used to simulate the interaction of the expected maintenance environment and required aircraft operations to determine the number of aircraft, maintenance manpower needed, and the number of spare parts and support equipment required to sustain war under some expected scenario. The LCOM system requires a thorough understanding of computer simulation and statistical techniques, as well as operational maintenance and manpower knowledge. We will discuss LCOM in more detail in a separate section later.

In an August 1979 technology report, Gordan Eckstrand emphasizes the increasing concern that the weapon systems procured by the Air Force be designed within manpower numbers and skill level restrictions.[7] Air Force regulations now require the use of LCOM during weapon system development. However, Mr. Eckstrand points out, as the use of LCOM becomes more prevalent, the model use needs to be simplified and results continually validated. He further discusses the manpower levels versus training versus system design tradeoff and the requirement for further research and development in the human resources area.

Mr. S. Craig Moore of the Management Sciences Department, Rand Corporation, addresses the manpower issue in terms of skill level and pay grade.[8] He designates five categories to study direct work accomplished. These categories are reproduced as follows:

Manpower Category	Skill Level	Pay Grade
1	3	E-1, E-2, E-3
2	5	E-3, E-4
3	5	E-5
4	7	E-5, E-6
5	7	E-7

He then discusses work performed upon eleven types of equipment in terms of who (which category) might perform each portion of the work (troubleshoot, repair, verify) and the time required for each portion. The eleven types of equipment addressed in this preliminary report are:

Turbine generators	Low pressure compressors
Gasoline generators	Turbine compressors
Motor generators	Cabin leakage testers
Portable lights	Engine hydraulic stands
Heaters	Motor hydraulic stands

High pressure compressors

Mr. Moore discusses the average frequency with which each task is required during peacetime and wartime and uses what he calls a task flow (a consecutive series of required maintenance jobs) method to illustrate the expected time versus level for each task. For each of the eleven types of equipment he develops an expected time to repair, troubleshoot (analyse), and verify based upon the manpower category utilized. For example, he uses a --[4]--[2]--[4]-- portion of a job to represent a task that is troubleshot by a skill level 7 Staff or Technical Sergeant, repaired by a skill level 5 Sergeant or Airman First Class, and verified by the skill level 7. Thus, he illustrates the expected job/task completion time for each of the eleven types of equipment under any mix of maintenance categories selected.

Captains Bruce French and Robert Steele, in a thesis presented to the School of Systems and Logistics of the Air Force Institute of Technology, address the productivity/ capability of maintenance organizations as a function of authorized skill level and authorized number of personnel versus actual skill levels and numbers of people assigned to the organization.[9] For example, they used an organization authorized 60 personnel but assigned 58 as follows:

Manpower Grid

		Authorized	Assigned
Skill Levels	SL7	10	7
	SL5	20	16
	SL3	30	35
	Total	60	58

Through the use of this manpower grid they illustrate that both the total number of assigned maintenance personnel and skill levels of the individuals involved contribute to the overall productivity of the organization. In this particular example both the total number of personnel, which are then portioned into the several skill level-grade classifications through another computer program giving all work centers the same ratio of skill levels. They stress that all work centers do not require the same ratio of skill levels and that the relative productivity of 3-level versus 5-level personnel has not been established.

Although LCOM can currently be used to forecast the effect of total manpower differences in any work center upon mission accomplishment, it has not been used to address the skill level portion of the problem.

The objective of the thesis was to develop relative productivity factors for 3, 5 and 7 skill levels as pertains to F-4E aircraft maintenance organizations. These relative productivity factors were intended to provide a means to analyse the productive capability of a maintenance organization. They considered three methods to determine the relative productivity factors:

1. Direct work measurement at the work locations.
2. Opinion survey of knowledgeable people.
3. Statistical analysis of available data.

Due to the scope of the study and expense involved, they selected statistical analysis of available data.

They attempted to use the following regression model to establish the relative productivities of each skill level:

$$\hat{P} = \alpha + \beta_3 X_3 + \beta_5 X_5 + \beta_7 X_7$$

where

$\hat{p}$ = estimated productivity of the organisation

X_i = the number of people in skill level i

β_i = the relative productivity of skill level i

α = a constant

Although unable to develop the relative productivity factors, they did bring many other considerations to light. Base differences, weather conditions, extreme data inaccuracies and other factors greatly complicate this method of productivity analysis.

In 1972, under a contract with the Air Force Human Resources Laboratory, McDonnell Douglas Astronautics and McDonnell Aircraft Company performed a study to determine the relationship between subsystem design characteristics training costs, training difficulties, and job performance.[10] They used stepwise regression and factor analysis techniques to derive equations to predict performance time, technical order reading time, number of errors, and training equipment costs.

The purpose of the current research effort is to develop a means to assess the relative productivity of maintenance personnel possessing different skill levels. From the studies discussed it is clear that data relating to maintenance task times suffers from extreme inaccuracies. It is also clear that the study time and expense of actual work measurement of the numerous tasks, and conditions under which they must be performed, would be prohibitive. Actual test, especially under simulated war conditions would be impossible. The methodology utilized in this research seeks to overcome the shortcoming of previous works while recognizing the need for a cost effective and versatile model. LCOM is the primary tool used in this research. An understanding of this model is necessary to appreciate this research effort.

The Logistics Composite Model

As noted, the maintenance manpower resources required to support a complex aircraft weapon system represents a large portion of the total resources of Air Force operational commands. Due to escalating personnel costs and congressional reductions in overall armed forces manpower levels, an accurate determination of required maintenance manpower is essential.

Maintenance manpower requirements have historically been based upon peacetime reports of maintenance manhours per flying hour. For new systems, contractor estimates were used for initial manning. Differing flying rates, mobility requirements, spare parts levels, and the impact of number of aircraft, among other problems, led to the search for a better technique to estimate manning. After several methods were considered, computer simulation was selected because of its systematic in-depth analysis of the maintenance operation and flexibility in terms of "what if" questions.

Due to the need to represent an entire flying operation including complex interrelationships that exist between support resources (personnel, equipment, spare parts and facilities) a highly versatile model was developed, the Logistics Composite Model (LCOM). See Keller's Student Training Text for an in-depth discussion.[11]

LCOM was developed in the mid-1960s through a joint effort between the Air Force Logistics Command and the Rand Corporation. It is a Monte Carlo simulation model written in SIMSCRIPT II.5. LCOM simulates the interactions of aircraft operations and support functions at an Air Force base. By replicating the logistics process, LCOM addresses the utilization of support resources (people, parts, facilities and equipment) and the impact of their interactions and shortages upon the capabilities of the flying unit.

LCOM consists of a preprocessor program, a simulation program, and a series of postprocessor programs. Figure 2, reproduced from Keller, illustrates how these programs interrelate.

The preprocessor, or Input Program, reformats and edits input data to make it useable by the Simulation Program. This data describes the environment to be simulated and prescribes the initial values for required variables. The data also describes mission requirements (takeoff time, number of aircraft required, sortie lengths, etc.)

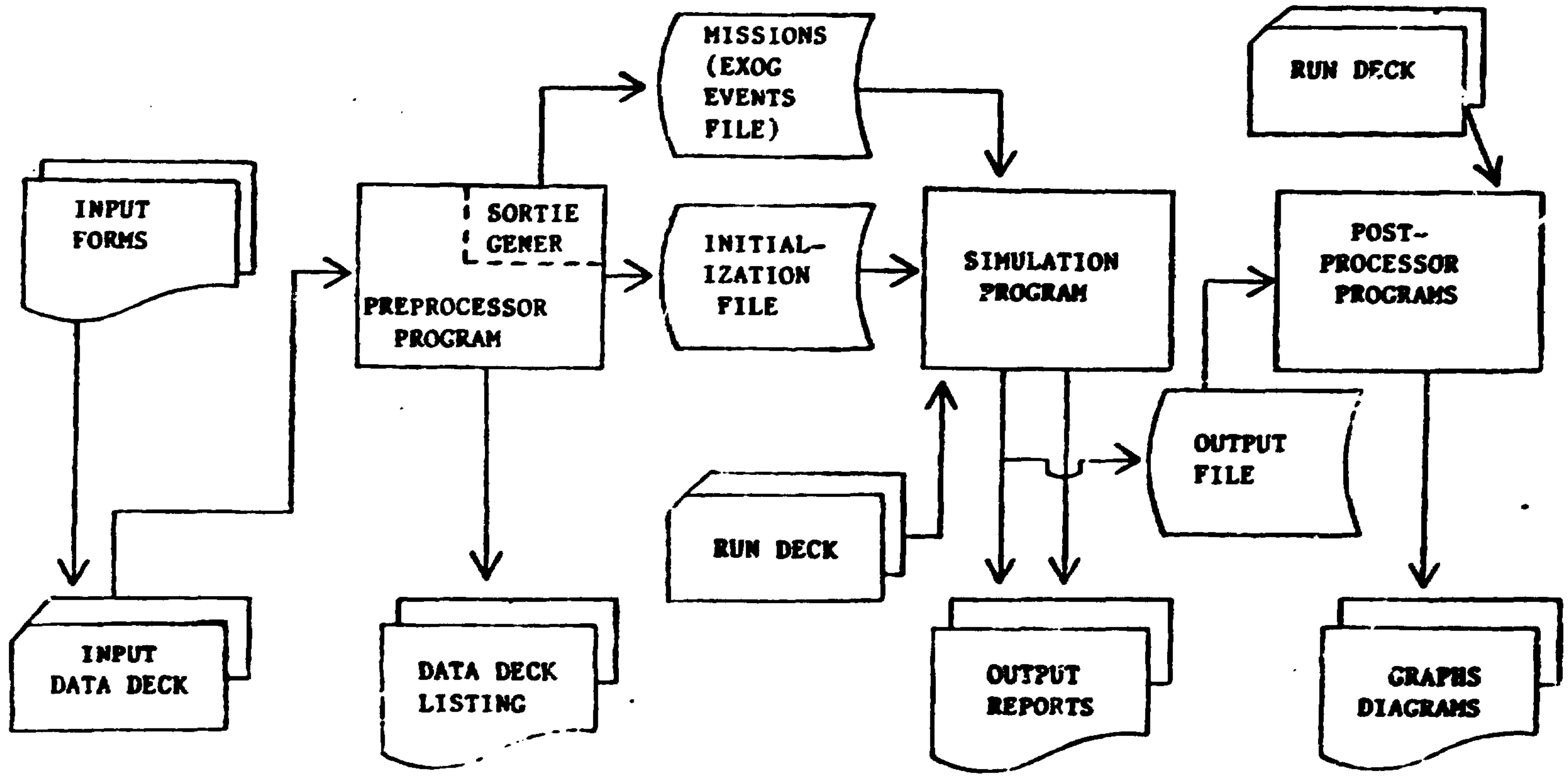


FIGURE 2. Overall Structure of Logistics Composite Model

The Simulation Program is controlled by the output of the preprocessor and simulates the flying of aircraft and the accomplishment of servicing and maintenance tasks. These tasks include refueling, weapons loading, repair on the aircraft, in flight line shops, etc. This program also handles the utilization and interaction of resources, queuing problems, and statistical record keeping. User provided input data determines the degree of detail for all activities in the simulation. All activities and their interrelationships are identified and described by maintenance task networks. For each task, the user supplies the task duration distribution and the types and quantities of resources required as well as probabilities and interrelationships with other tasks. The total number of resources and resource mix is limited only by computer capacity.

During the simulation, available aircraft are processed through presortie activities toward scheduled missions and returning aircraft are processed through postsortie activities. See Figure 3 for the outline of the sequence of events. From the user supplied mission schedule at the user established lead time, the model draws aircraft from the availability pool and processes the appropriate number of aircraft through the presortie tasks. If presortie tasks are completed in time to meet the schedule, the mission is flown and postflight or through flight processing occurs.

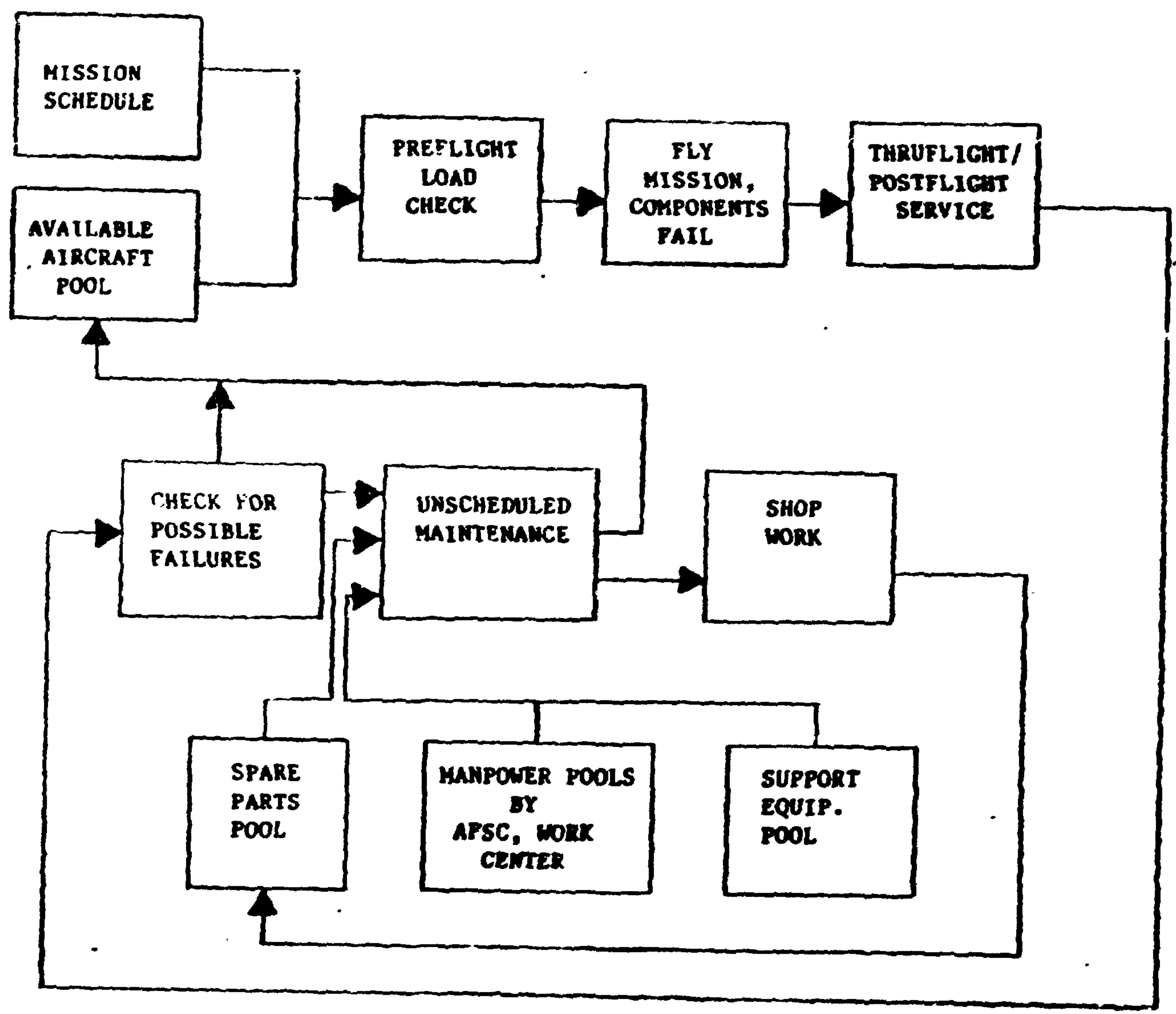


FIGURE 3. The Simulation Process

The program checks for failures in aircraft subsystems (which fail according to user specified parameters) and after all processing and repairs are completed, the aircraft is returned to the available pool to await assignment to another mission. See Figures 4 and 5, respectively, for examples of the servicing and repair networks.

The output of the Simulation Program is the Performance Summary Report (PSR) and is produced at user specified intervals during the simulation period which is also user specified. The PSR summarizes statistics in six functional areas:

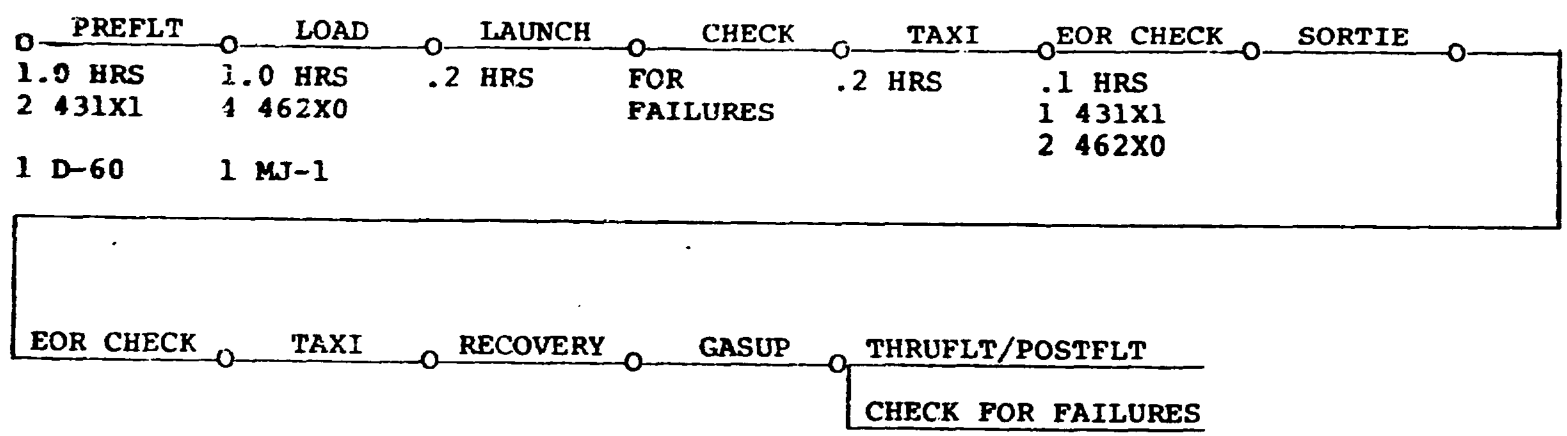
1. Operations
2. Aircraft
3. Personnel
4. Shop Repair
5. Supply
6. Equipment

Other status information is available upon user request. See Figure 6 for an example of a PSR.

The postprocess programs provide the user with four additional (optional) capabilities:

1. Postprocess Summary Statistics - PSR information in graphical form.

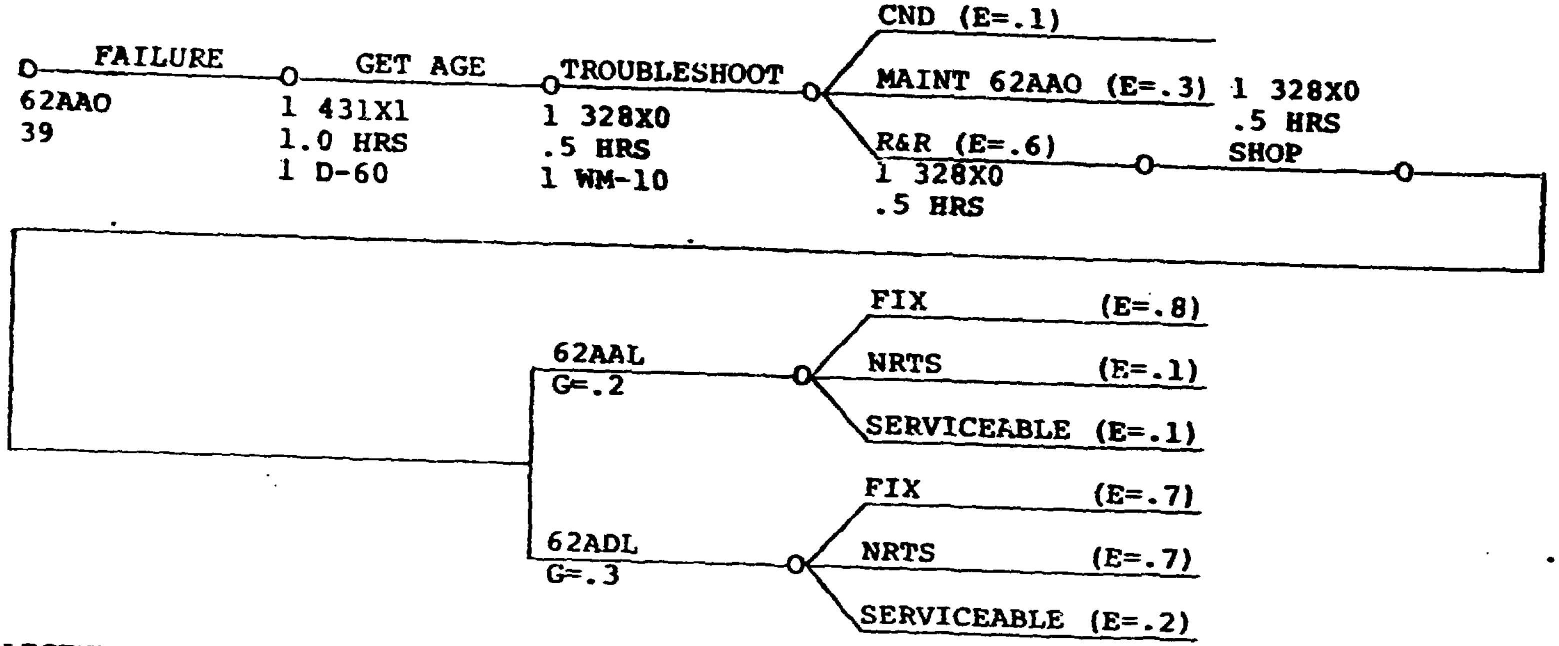
2. Postprocessor Display - Graphical displays of selected aircraft.



LEGEND

PREFLT	-	PREFLIGHT PREPARATION TASKS
LOAD	-	UPLOAD WEAPONS (GUNS, BOMBS, MISSILES)
LAUNCH	-	ASSIST PILOT IN STARTUP
TAXI	-	AIRCRAFT GROUND TRAVEL TO RUNWAY
EOR CHECK	-	END OF RUNWAY CHECK TO ARM/DISARM WEAPONS
SORTIE	-	TIME FROM AIRCRAFT TAKEOFF TO FULL STOP LANDING AND ENGINE(S) SHUTDOWN
RECOVERY	-	GUIDE TAXI IN AND ASSIST PILOT IN SHUTDOWN
GASUP	-	REFUEL AIRCRAFT
THRUFLT	-	PREPARE AIRCRAFT FOR ANOTHER MISSION OR STORAGE
POSTFLT	-	POSTFLIGHT AIRCRAFT MAINTENANCE AND SERVICES
431X1	-	FLIGHT LINE MAINTENANCE SPECIALIST
462X0	-	WEAPONS LOADING SPECIALIST
D-60	-	MOBILE POWER CART
MJ-1	-	MAINTENANCE LOADING JACK

Figure 4. Example Main Network



<u>LEGEND</u>

AGE	-	GROUND SUPPORT EQUIPMENT
CND	-	CAN NOT DUPLICATE
MAINT	-	MAINTAIN OR REPAIR ON AIRCRAFT
R&R	-	REMOVE AND REPLACE
NRTS	-	NOT REPAIRABLE THIS STATION (SEND TO DEPOT)
E	-	EXCLUSIVE PROBABILITY BRANCH
G	-	NONEXCLUSIVE PROBABILITY BRANCH (BUT AT LEAST ONE)
62AAO	-	NAME OF SYSTEM THAT FAILED
D-60	-	GROUND POWER CART
WM-10	-	SPECIALIZED EQUIPMENT TO CHECKOUT FAILED SYSTEM
431X1	-	FLIGHT LINE SPECIALIST
328X0	-	COMMUNICATIONS SPECIALIST
62AAL	-	SUBPARTS OF FAILED SYSTEM
62ADL	-	SUBPARTS OF FAILED SYSTEM

Figure 5. Example Subsystem Failure Network

P E R F O R M A N C E   S U M M A R Y   PERIOD FROM 30.0 TO 60.0   LEVEL 1

O P E R A T I O N S	TOTAL	CAS	CAPG	CAPA	INT	ESC	ALTG	ALTA	OTHER
1 NUMBER OF MISSIONS REQUESTED	434.00	113.00	36.00	56.00	117.00	98.00	0.	60.00	0.
2 NUMBER ACCOMPLISHED	411.00	112.00	29.00	49.00	108.00	97.00	0.	56.00	0.
3 PERCENT ACCOMPLISHED	94.70	99.12	96.67	87.50	92.31	98.28	0.	93.33	0.
6 NUMBER OF SORTIES REQUESTED	808.00	226.00	60.00	112.00	234.00	116.00	0.	60.00	0.
7 NUMBER ACCOMPLISHED	766.00	224.00	58.00	98.00	216.00	114.00	0.	56.00	0.
8 PERCENT ACCOMPLISHED	94.80	99.12	96.67	87.50	92.31	98.28	0.	93.33	0.
T1 NUMBER OF WEATHER CANCELS	32.00	14.00	0.	8.00	6.00	4.00	0.	0.	0.
T2 NUMBER OF WEATHER DELAYS	42.00	28.00	4.00	10.00	0.	0.	0.	0.	0.
T3 NUMBER OF ALERT REPLENISHMENT	44.00	0.	0.	0.	0.	0.	0.	44.00	0.
T4 NUMBER OF ATTRITIONS	0.	0.	0.	0.	0.	0.	0.	0.	0.
T5 NUMBER OF BAM REPAIRS	0.	0.	0.	0.	0.	0.	0.	0.	0.
T6 NUMBER OF AIR ABORTS(TOTAL)	572.00	180.00	28.00	75.00	151.00	92.00	0.	45.00	0.

A I R C R A F T	TOTAL	F4E	OTHER
13 NUMBER OF AIRCRAFT AUTH.(EUP)	24.00	24.00	0.
14 NUMBER OF AIRCRAFT-DAYS AVAIL	720.00	720.00	0.
15 PCT SORTIES(INCL ALERT)	5.03	5.03	0.
16 PCT UNSCHED MAINTENANCE	22.12	22.12	0.
17 PCT SCHED MAINTENANCE	23.59	28.69	0.
18 PCT NORS	0.	0.	0.
19 PCT MISSION RDIY STATUS	12.79	12.79	0.
20 PCT SERVICE + WAITING	.00	.00	0.
21 PCT OPERATIONALLY READY	31.38	31.38	0.
22 AVG. AIRCRAFT TURNAROUND TIME	6.33	6.33	0.
23 AVG. NO. OF SORTIES/ A/C /DAY	1.06	1.06	0.
24 FLYING HOURS	867.18	869.18	0.
T7 NUMBER OF FCF TASKS FLOWN	0.	0.	0.

P E R S O N N E L	TOTAL	141X2	316L1	321Q2	325X0	325X1	328E3	328X0	328X1	328X3	328X4
27 MANHOURS AVAILABLE (100)	48960.00	1440.00	1440.00	1440.00	1440.00	1440.00	1440.00	1440.00	1440.00	1440.00	1440.00
28 PERCENT UTILIZATION	.82	0.	.40	2.03	.16	.57	.24	.86	.38	1.52	.65
29 MANHOURS USED (10C	399.35	0.	5.72	29.23	2.34	8.23	3.41	12.35	5.44	21.98	9.43
30 PCT UNSCHED MAINTENANCE	41.95	0.	0.	100.00	100.00	99.49	0.	37.02	100.00	29.75	100.00
31 PCT SCHED MAINTENANCE	58.05	0.	100.00	0.	0.	.51	100.00	62.98	0.	71.25	0.
33 NUMBER OF MEN DEMANDED	52039.00	0.	1377.00	3612.00	316.00	1338.00	1674.00	1758.00	573.00	3071.00	889.00
34 PCT AVAILABLE (PRIME)	100.00	0.	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
35 PCT AVAILABLE (SUBST.)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
36 PCT PROV. BY EXPEDITE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
37 PCT PROV. BY PREEMPTION	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
38 PCT DEMANDS NOT SATIS.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
39 OVERTIME MANHOURS USED (100)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
40 SIMULATED MH PER FLYING HOUR	45.95	0.	.66	3.38	.27	.95	.39	1.42	.63	2.53	1.08

Figure 6. Example of a Performance Summary Report

3. Manpower Matrix - Summary data, by shift, for personnel utilization.

4. Postprocessor Parts Failure - Displays statistics relating to parts failure.

See Figure 7 for an example of the manpower matrix output.

The mission requirements for this study relate directly to the maximization of sorties produced per unit time. In order to compare 5-level and 3-level mission accomplishments, the same operations schedule is utilized for every simulation effort. This operation schedule calls for four aircraft maximum (two aircraft minimum) to takeoff every hour. Only a 24 UE (unit equipage - 24 airplanes available) organization was considered. This number of mission requests far exceed the capability of the simulated organization and results in a maximation effort.

Data Required and Collection Method

The data required for this project included:

1. A listing of all maintenance tasks related to the F-4E aircraft.

2. Failure rate information for each aircraft system, subsystem, or part.

3. The repair technique for each maintenance discrepancy, skill level requirements and associated repair times, probabilities of rework and associated safety information.

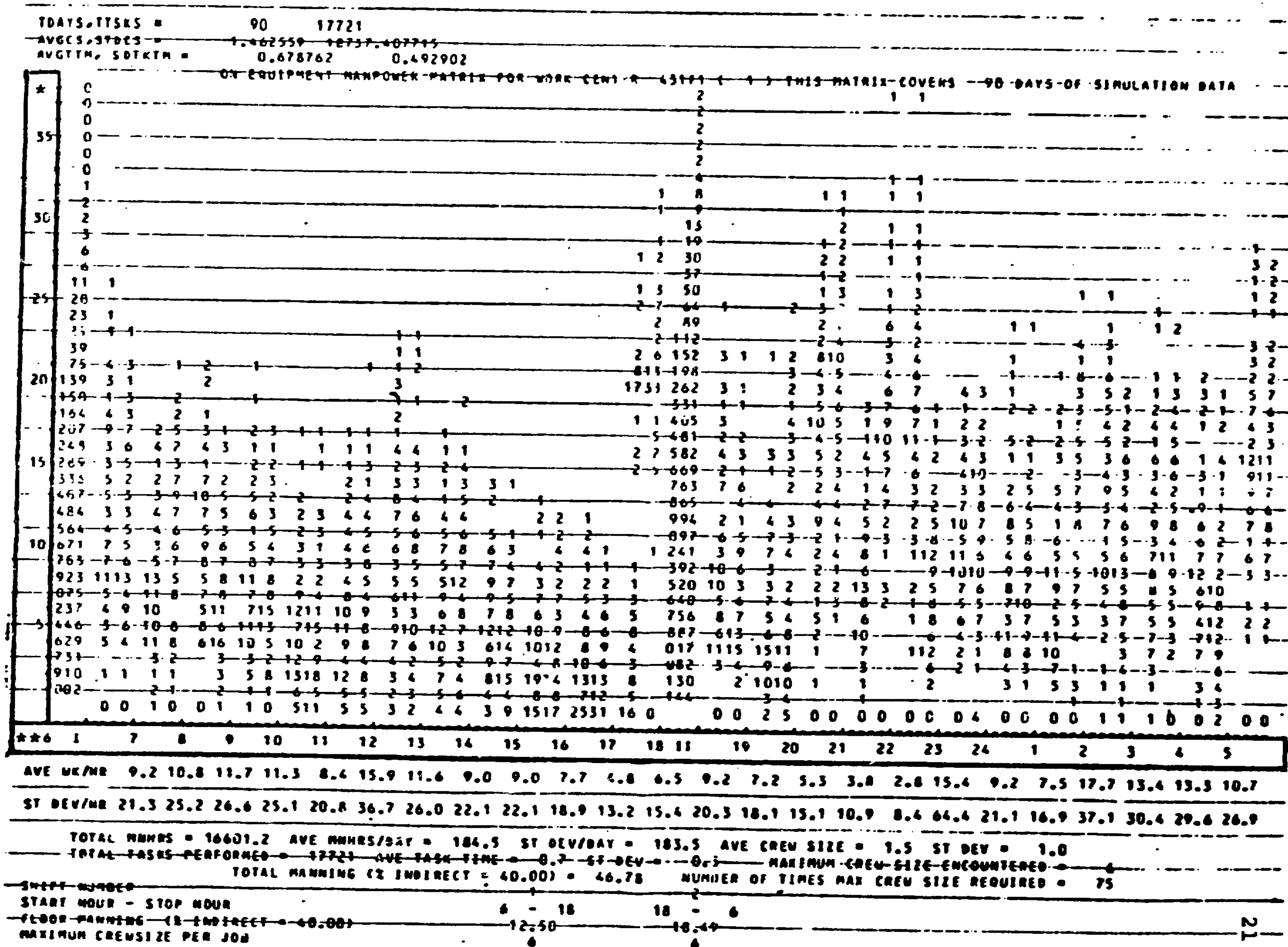


Figure 7. Example of a Work Center Manpower Matrix

L E G E N D

* Numbers in left hand column represent the number of repair personnel that might be busy at any time. Entries to the right of these (and above the hour of day row) represent the number of times during the simulation period that the indicated number of repairmen were occupied at that hour. For instance, suppose the simulation period was 30 days, and we found the number 13 to the right of the eleventh row (labeled 10 since there is a zero row) above the column sub-labeled 7. This entry would mean that 13 times during the 30 day simulation period there were precisely ten repairmen of this specialty occupied. The total of the digits above each hour of day entry must equal the number of days of the simulation period. This visual matrix display aids in the understanding of the queuing that takes place when we limit the manpower available.

** This is the hour of day row. It relates in a 24 hour clock and also indicates the shift change time and shift number.

Figure 7. Example of a Work Center Manpower Matrix (continued)

A list of all maintenance tasks can quickly be derived from the work unit code manual for the selected aircraft. For this study we utilize T.O. 1F-4E-06, Technical Manual Aircraft Maintenance Work Unit Code Manual USAF Series F-4E Aircraft, dated 1 June 1978, changed 1 August 1979.[12]

The work unit code consists of five or less numeric and alphabetic characters and is used to identify the system, subsystem, and component requiring maintenance.

All maintenance performed upon United States Air Force aircraft is recorded on Air Force Form 349 by the maintenance specialists who perform the work. The specialist records the work unit code to identify what part of the aircraft was serviced, a code that identifies what type of maintenance was performed, the number of maintenance men required to perform the work, the Air Force Specialty Code(s) of the specialists, and the elapsed time of the work, as well as other information. This information is then entered into the Air Force Maintenance Data Collection (MDC) system along with aircraft flying time, number of sorties (flights), station where maintenance is performed, home station of aircraft, and aircraft identification. See Appendix A for a discussion of the MDC system, reproduced from Air Force Manual 66-1.[13]

Failure information for the F-4E aircraft was retrieved from the MDC system and processed to recover the failure rate (average number of sorties between maintenance actions) for each system, subsystem and component. Due to biases caused by false or inaccurate reporting in the MDC information, it has been found that the elapsed time and crew size information is not always reliable. However, the number of failures, flight time and other information has been found to be accurate. Therefore, this research utilized the MDC system to collect information pertaining to the failure rates of F-4E subsystems and parts. For each system actual number of failures during a time period are divided by the total of sorties flown during the period. This mean value is then used in an exponential distribution to determine simulation failure sequences. Lieutenant Colonel Donald Tetmeyer explains the rationale in one of his publications.[14]

There are various techniques that could be utilized to estimate the time required to perform maintenance upon aircraft. Some of these techniques are:

1. Direct work measurement
2. Work sampling
3. Analysis of Air Force MDC data
4. Opinion survey of maintenance experts

The basic method used in this research to collect maintenance data has been developed over the past 15 years through extensive efforts by several manpower specialists. Due to errors and false information found in the MDC system, an interview technique, called an operational audit, was used to determine the mean task times for each maintenance task associated with an aircraft weapon system under study.

The times are determined by discussion with highly skilled maintenance supervisors and confirmed by discussion with maintenance personnel who actually do the work. The consensus average task time for every maintenance task, required crew size, and necessary support equipment are thus determined. This method normally requires from 2 to 10 hours per work center (there are 15 to 30 work centers for each aircraft maintenance system), depending upon the size of the work center, skill of the interviewer, and understanding of the maintenance personnel. For each task, the number of Air Force maintenance personnel interviewed depends upon the similarity (range) of the estimates received. Little variance has been found between independent estimates for task times received from different maintenance specialists. Whenever differences larger than .3 hours are detected the specialists involved are asked to convene and produce a group consenses as to the "correct" task times. This seldom happens.

In an effort to validate this methodology the Tactical Air Command (TAC) used time study techniques (performed by the Air Force agency that is responsible for manpower utilization through a management engineering team at Seymour Johnson Air Force Base, North Carolina) to check many of the task times reported for the ongoing study of the F-4E aircraft.[15] Lieutenant Colonel Richard Gunkel headed a group that analyzed task time data to determine the type distribution that best represents maintenance task times. As a result of this study the team recommended the use of the Log Normal Distribution with the standard deviation equal to 29 percent of the mean task time. The study also confirmed that the interview technique produced acceptable mean task times. McDonnell Douglas Corporation is currently conducting a study aimed at the update of variance estimate for aircraft maintenance tasks. When their study is complete we should possess better information about task time distributions and factors affecting deviations from mean task time.

In a further effort to validate the entire simulation approach the group ran the simulation with operational requirements identical to those for the actual operational unit at Seymour Johnson Air Force Base. The results of the simulation were reported to be within three percent of actual results of the unit in terms of mission accomplishment, manhours expended in each work center, and aircraft turn time.

It should be noted that time study techniques require 50 to 200 times as long (in both manhours and elapsed time duration) to collect the same data that can be obtained through operational audit techniques. Due to the nonrepetitiveness of many of the maintenance tasks involved (some occur only once in several hundred missions) and the varying conditions under which they might be required (rain, snow, cold, pressure of priority missions, war, etc.) time study techniques may be no more accurate than operational audit techniques. For this study operational audits were conducted at Seymour Johnson Air Force Base during several visits during 1979. From the work unit code manual for the selected example aircraft each maintenance specialist identified all tasks for which his/her specialty is responsible. Each task was identified for the type of work (remove and replace, repair on aircraft, troubleshoot, inspect and verify, etc.) required when a write up (discrepancy) has occurred. The specialist was then asked to estimate the time required to complete each task when the work is performed by 5-level and 3-level maintenance personnel. Maintenance crew size, rework probabilities, safety and other related information were requested from each specialist. See Appendix B for an example of the operational audit technique. See Appendix C for an extract from the list of job titles, 5-level maintenance repair times, and 3-level maintenance repair time.

LCOM Constraining

When the LCOM simulation is debugged and the unconstrained results analyzed the number of maintenance personnel in each work center is limited and the simulation rerun. This initial constraining is based upon experience as well as the numbers of personnel called for in the unconstrained simulation. Personnel are added or dropped from the various work centers through an iterative process until the reduction of one specialist from any work center causes the simulation results to be less than that called for in the planned scenario. Usually this is 95 percent of the unconstrained accomplishments in terms of sortie rate.

Although it is possible for different manning levels to result in the same output in practice this rarely occurs. In any event, the LCOM simulation is analyzed until the manning that results is believed to be the minimum that will achieve the desired sortie rate.

Safety, pilot morale and maintenance concepts also relate to the current research. Each of these problems was considered throughout the interview and research processes.

Safety Problems

Each of the maintenance specialists was asked about safety problems that might occur if a greater percentage of maintenance personnel possessed only a skill level 3. Also, quality control personnel were interviewed in an effort to determine safety implications of increased 3-level utilization. All persons interviewed expressed the opinion that, due to required adherance to technical orders and inspection by higher skill level maintenance supervisors, safety (ground or flying) would not constitute a problem. A review of quality control records did not establish a basis for believing 3-level maintenance is inherently less safe than

5-level performance. However, this area may require extensive additional research prior to forming firm conclusions about safety implications.

Pilot Morale Problems

In an attempt to assess a possible impact of a maintenance skill level decrease upon pilot morale, the author designed and distributed a questionaire to a sample of Air Force pilots at Wright-Patterson Air Force Base, Ohio. See Appendix D for a copy of the survey and some initial responses.

The first four questions were intended to determine if there is a pilot morale implication and last two questions were intended to elicit additional information about pilot reactions to maintenance skill level changes. Due to the small sample size and the subjectivity of the responses, it is not possible to draw firm conclusions about maintenance skill level reduction effect upon pilot morale. However, one might note the alternatives suggested by concerned pilots. A more in-depth survey of aircraft crew members and maintenance personnel is suggested prior to implementation of any planned skill level reduction.

Production Oriented Maintenance Organization

Production Oriented Maintenance Organization (POMO) refers to a maintenance organization method that seeks to gain greater overall productivity by utilizing available maintenance personnel to assist in tasks that do not fall within their specialities. POMO has been implemented and is being evaluated at many Tactical Air Command bases. Although POMO was not considered during this study, LCOM now has the capability, through the use of resource substitutability to incorporate POMO into future studies. See Keller for an in-depth explanation of POMO.[16]

Research Objectives

The objectives of the current research effort are:

1. Provide a method to account for various skill levels in maintenance manpower forecasting and mission capability assessment.

2. Illustrate the use of digital simulation to provide a means to analyse the effects of skill level changes.

3. Demonstrate the use of computer simulation to verify sampling techniques.

4. Demonstrate the use of interview techniques to establish task times for different skill levels within a complex aircraft maintenance organization.

CHAPTER II

RESEARCH METHODOLOGY

Research Description

The objective of this research is to develop a method whereby an analyst can forecast the effects of varying the skill levels of personnel within a military aircraft maintenance organization. To accomplish this objective the author has adapted a large scale computer simulation model of a military aircraft maintenance organization. The inputs to this computer simulation model are varied to test the effect of various maintenance task times that relate to the possible skill levels of the maintenance personnel that make up the organization. These task times are developed through an interview technique with maintenance specialists. Task times for each task and each skill level maintenance specialist are collected for the F-4E aircraft system. The computer simulation model is then used to compare the results of several possible scenarios of differing average skill level within the maintenance organization.

Various sampling techniques are used to determine the least amount of interview time and computer model manipulation that will provide the same simulation results as the complete interview encompassing all maintenance tasks involved with the subject aircraft. The purpose of the sampling is to reduce the cost of the interview process (called the "operational audit").

The costs associated with a complete operational audit relate directly to manhours required and elapsed time. A single interview will discuss task times for up to 100 different jobs. Each job may entail 10 minutes of discussion. Usually 2 or 3 specialists are interviewed for each work center. Thus, we are talking about some 20-30 minutes to develop the task time for each job. For the F-4E aircraft, there are some 2,000 tasks which relates to about 670 interview hours. The sampling technique developed in the research calls for about 150 tasks to be sampled. This relates to 50 interview hours. Thus the sampling technique results in considerable time saving in the interview task alone.

Also the sampling technique results in simplified computer model manipulation and thus saves additional time. Through the techniques developed in this research the total elapsed time to adapt a current computer simulation model to account for an average skill level change (this includes interview time and computer simulation model adaptation) can be cut from four months to about one month.

In particular, this study defines and demonstrates the utility of the "operational audit" technique to acquire the estimated task times for all the maintenance tasks performed by average (5-level) and low (3-level) skilled personnel performing maintenance upon the F-4E aircraft. However, heretofore, the operational audit interview technique has not been utilized to collect data pertaining to skill level productivity differences. This research adapts the operational audit technique to collect data pertaining to task times for 5-level and 3-level maintenance personnel.

The information gained in the operational audit is then used in an LCOM computer simulation model to prepare a series of computer simulation runs. These simulation results will compare 5-level and 3-level skilled maintenance personnel productivity. In Figure 8 these 5-level and 3-level simulation efforts will be referred to as series A and B, respectively. The effect of the skill level reduction upon mission accomplishment, maintenance manhours per flying hour (MMHPFH), and manning will be analysed. A separate section will explain what is considered as a significant difference.

Series A and B are computer simulation models of the same maintenance organization. Series A incorporates all 5-level maintenance task times as determined by the operational audit technique. Series B incorporates all 3-level maintenance task times that are also determined through the operational audit technique. All maintenance tasks are included in the operational audits that develop inputs (maintenance task times) for series A and B. These tasks times, as they differ for 5-level and 3-level skilled maintenance personnel, are the only difference between series A and series B computer simulation models.

If there is no significant difference between the series A and series B result in terms of mission accomplishment, manhours expended, and number of personnel required we can determine that no adjustment need be made to the original 5-level model to enable us to forecast the effect of using lesser skilled maintenance personnel. Indeed, this result would mean that lesser skilled maintenance personnel are just as productive as the average skilled personnel.

If there is a significant difference between the series A and series B results we will be able to say not only that a difference exists, but we can say what the relative productivity difference is between a maintenance organization manned by all 5-level personnel and one manned by all 3-level personnel. In this case the research will continue in an effort to determine the simplest method to forecast the magnitude of the skill level productivity difference.

Due to the large amounts of time required to perform a complete operational audit we would like to test the feasibility of incorporating various sampling techniques into the operational audit phase of data accumulation. The sampling that we are evaluating pertains to the number or percent of maintenance tasks that we must include in our operational audit so as to develop a task time difference factor for a maintenance organization or suborganization. To be feasible, these sampling task time difference factor(s), when incorporated into the 5-level simulation model must result in the same productivity and manning as the 3-level model that was developed from a full operational audit. See Figure 8 for the flow diagram in the quest for the simplest operational audit sampling techniques.

Figure 9 represents a mathematical approach to this research design. One can visualize this as the LCOM model of the real world. The vertical columns then represent the specific limitations or manipulations required to analyze the various techniques to simulate the real world situation. The real world side is narrowed to the F-4E organization. It is further reduced to the expert opinions of the task times required. Then the real world is narrowed through averaging, sampling and grouping techniques.

The LCOM simulation of the real world is limited to the F-4E aircraft. Inputs are obtained through the operational audit technique to compare 3-level and 5-level output parameters. Further comparisons are made using the LCOM simulation and averaging, grouping and sampling techniques.

First let us average the percent expected time differences to complete every task (including rework probability) with

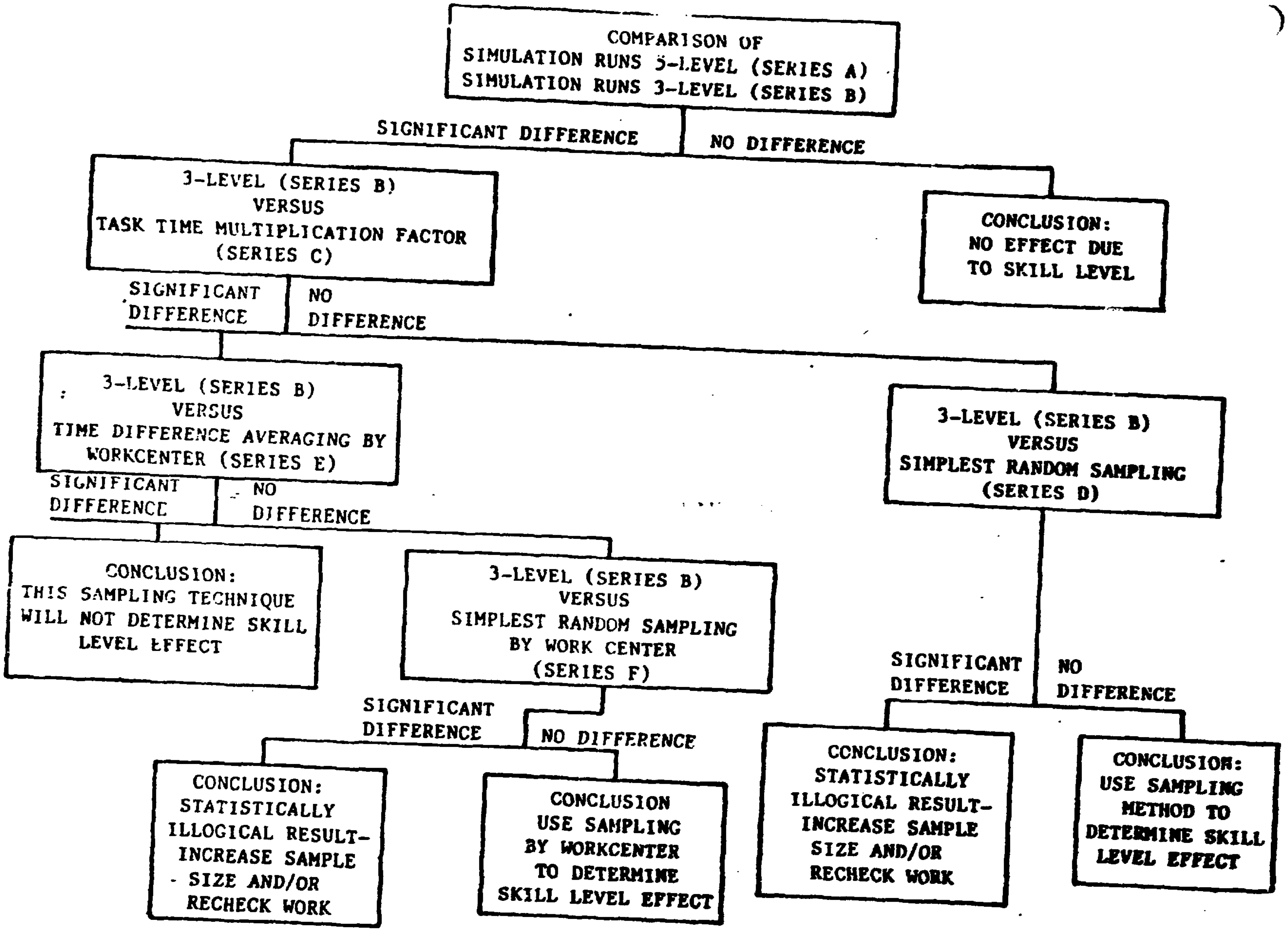


FIGURE 8. Flow Diagram for Operational Audit Sampling Technique.

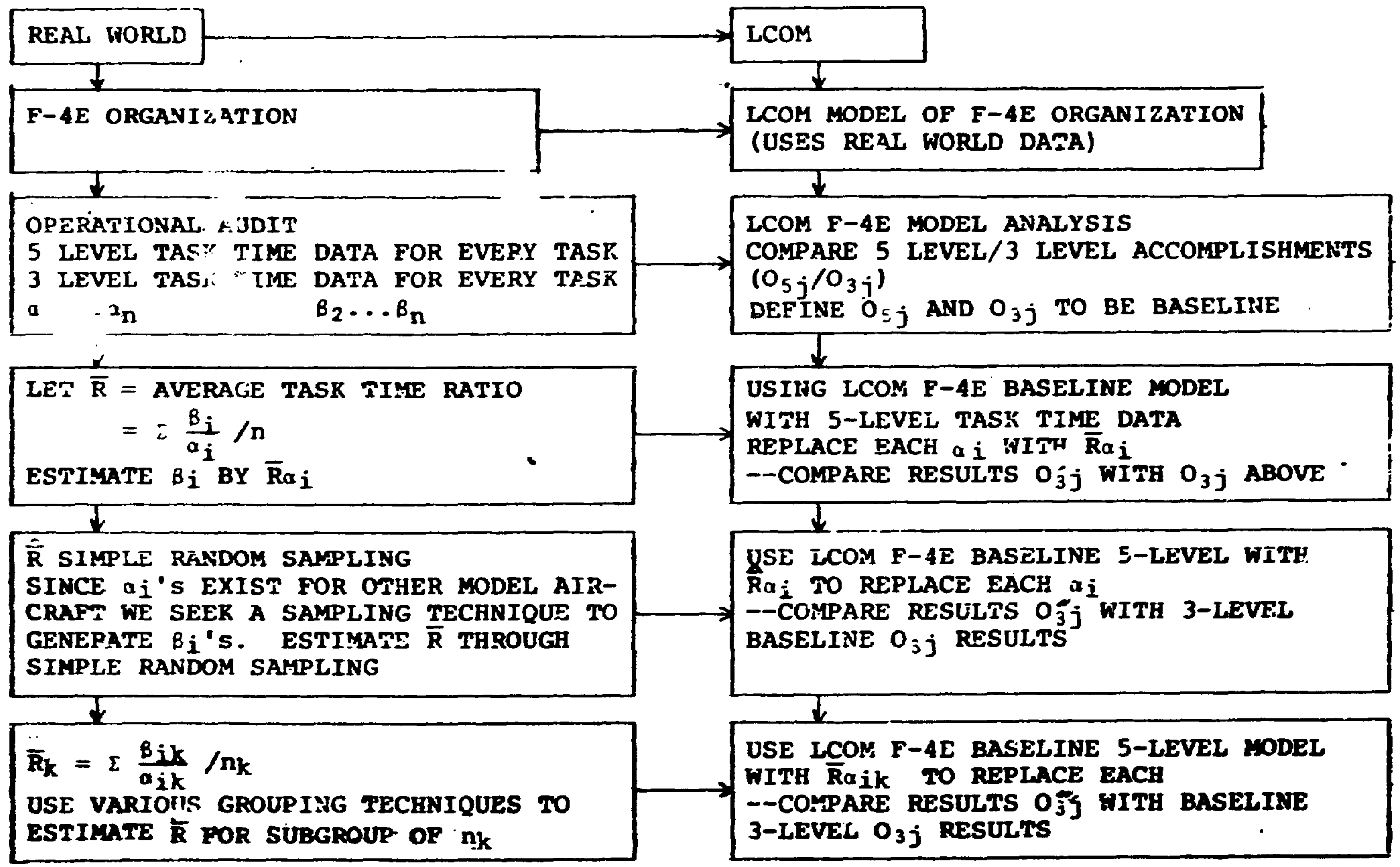


Figure 9. Research Diagram

α_i	5-LEVEL TASK TIME TO COMPLETE TASK i
β_i	3-LEVEL TASK TIME TO COMPLETE TASK i
O_{5j}	5-LEVEL OUTPUT (RESULTS) FOR PARAMETER j
O_{3j}	3-LEVEL OUTPUT (RESULTS) FOR PARAMETER j
O_{3j}'	3-LEVEL OUTPUT THROUGH AVERAGING TECHNIQUE
O_{3j}''	3-LEVEL OUTPUT THROUGH SIMPLE RANDOM SAMPLING
O_{3j}'''	3-LEVEL OUTPUT THROUGH GROUPING TECHNIQUE
R	RATION OF 3-LEVEL TASK TIME/5-LEVEL TASK TIME
$\bar{R}$	AVERAGE R RATIO
$\tilde{\bar{R}}$	ESTIMATE OF $\bar{R}$
$j = 1$	NUMBER OF SORTIES PER AIRCRAFT PER DAY ACHIEVED IN LCOM SIMULATION EFFORT
$j = 2$	NUMBER OF MAINTENANCE MANHOURS PER FLYING HOUR
$j = 3$	AVERAGE PRESORTIE PREPARATION TIME (ELAPSED TIME)
$j = 4$	AVERAGE POSTSORTIE MAINTENANCE TIME (ELAPSED) TIME
$j = 5$ ⋮ 32	AVERAGE NUMBER OF MAINTENANCE PERSONNEL MANHOURS PER FLYING HOUR FOR WORK CENTER j-4

Figure 9. Research Diagram (continued)

3-level skill as opposed to 5-level skill. Applying this factor to all maintenance tasks in the original 5-level baseline simulation we rerun a series of simulations. The results of this series (C) are compared with the first series of 3-level skill simulation runs (series B). If there is a significant difference, this averaging technique is not valid so we would proceed with the analysis of task times averaged by work center.

If, on the other hand, series B and C are not significantly different a portion of the tasks will be sampled. The percent time differences will be averaged, and computer simulation series D performed. If series D and C are not significantly different, one can conclude that the effects of skill level differences upon mission capability can be estimated through this sampling technique and computer simulation. Only a sampling (see section on Sampling Size) of other aircraft maintenance repair time differences needs to be analyzed to use the computer simulation technique to estimate skill level effect (indeed, the same correction factor may apply to other aircraft systems as well, but will not be validated at this point).

If series B and C are not significantly different, series D is merely a confirmation as to the size of the sample required to estimate the population mean (here the population mean is the mean of the series C results).

If series B and C are significantly different, the task time differences by work centers can be averaged and computer simulation series E performed. If there is a significant difference between series B and E, the sampling technique is not justified. However, if no significant difference is detected, the task time differences by work center is a valid method to determine skill level effect. Furthermore, randomly selected samples from each work center can be used to test if the work center effect can be estimated by a technique similar to that described above. Figure 8 gives a guide to the simplest operational audit sampling technique.

Data developed from the above research plan will be presented as follows:

TABLE	FIG. 8 SERIES	SORTIES/AIR-CRAFT/DAY	MMHPFH	SKILL LEVEL	TASK TIME COMP. METHOD
3, 5	A	2.3	37	5	Operational Audit
4, 5	B	1.8	50	3	Operational Audit
6, 7 & 11	C	1.7	55	3	Averaging/ Simple Random Sampling
8, 9	D	1.7/1.8	54/49	3	Work Center Grouping
10	E	1.8	51	3	Combined Grouping

Sample Size

Suppose, for any work center, we wish to take a sample that will insure a 95 percent probability that the error of the estimate of the sample mean ($\bar{X}$) percent time increase will not exceed 5 percent of the mean. For large sample sizes, $\bar{X}$ tends to be normally distributed with mean μ and variance σ^2/n. Thus for a 95 percent confidence interval we have

$$P\left[\bar{X} - \frac{1.96\sigma}{\sqrt{n}} < \mu < \bar{X} + \frac{1.96\sigma}{\sqrt{n}}\right] = .95$$

Therefore, for an error of the estimate to be $.1\bar{X}$, we set this value equal to $\frac{1.96\sigma}{\sqrt{n}}$ and solve for "n".

This gives

$$\sqrt{n} = \frac{1.96\sigma}{.1\bar{X}}$$

Since we do not have σ let us substitute the sample estimate "s" as an approximation.[17] Also, since we are anticipating a small value of "n", we will use the "t" distribution to obtain the coefficient for $s/\sqrt{n}$. Now we can use the "s" and $\bar{X}$ for each work center in a progressive or iterative fashion to keep an ongoing $\bar{X}$ and "s" and add new random samples until the formula

$$n = \left[\frac{t\ s}{.1\bar{X}}\right]^2$$

gives a value of "n" that is less than or equal to the current number of samples for the work center under consideration. As a first effort, 25 samples (for all work centers that have more than 25 tasks, elsewise a 100 percent sample) were drawn from each work center. The computed mean, sample size, sample variance, number of samples required for a 95 percent confidence of work center mean task time within the range $\bar{X} \pm .1\bar{X}$ and the actual 95 percent confidence range for the current sample are presented in Table 1. For reasons that will be apparent later, the statistical techniques and number of samples chosen is sufficient for the purpose of the study.

Some of the parameters that can be used in such a test include:

1. The work hours for each work center.
2. The average preflight preparation times.
3. The average postflight service time.
4. The total number of sorties accomplished.

As explained in the previous section, baseline (series A or B as appropriate) results are compared to each progressive experimental design step. The significance can be estimated by using an F-test. The null hypothesis (H_o) in each case will state that there is no difference between the mean value of the parameter under consideration for the baseline 3-level simulation and the alternative method being compared. In this way we can progressively compare the baseline 3-level output to the baseline 5-level, the 3-level using averaging, the 3 level using simple random sampling, and the 3-level using group techniques.

To calculate the power of the F-test, four quantities must be known:

n - the number of observations in each sample

α - the significance level

TABLE I. Sampling Data

WORK CENTER →	Sorties Per Aircraft/Day	Maintenance Manhour Per Flying Hour	Average Preshift Time	Average Postsortie Time	Bomb Navigation 32102	Automatic Flight Control 325X0	Instruments 325X1	Communications 328X0	Navigation 328X1	Electronic Warfare 328X3	Inertial Navigation 328X4	Sensors 329X0	Photographic 406X1	Electrical Systems 423X0	Environmental Systems 423X1	Egress 423X7
$\bar{x}$ SAMPLE MEAN*					1.51	1.58	1.46	1.36	1.32	1.61	1.36	1.37	1.46	1.46	1.44	1.69
S^2 SAMPLE VARIANCE					.236	.074	.098	.114	.057	.160	.110	.115	.098	.098	.106	.081
n REQUIRED FOR 95% CONFIDENCE $\bar{x} \pm .1\bar{x}$					44	13	20	27	16	26	25	27	20	20	23	16
SAMPLE CONFIDENCE INTERVAL $\bar{x} \pm$					.131	.072	.089	.106	.075	.103	.101	.106	.088	.084	.094	.074

	Fuel Systems 423X3	Pneudraulics 423X4	Aerospace Ground Equipment 423X5	Jet Engines 426X2	Flightline Maintenance 431F1	Reclamation and Repair 431R1	Special Duties 431Y1	Munitions Maintenance 461X0	Gun Services 462C0	Weapons Loading 462L0	Weapons Release 462U0	Machine Shop 531X0	Metal Processing 531X1	Structural Repair 531X3	Corrosion Control 531X6	Non Destructive Inspection 531X9
$\bar{x}$ SAMPLE MEAN*	1.56	1.50	1.36	1.96	1.58	1.64	1.31	1.5	1.18	1.47	1.3	1.67	1.44	1.56	1.38	1.5
S^2 SAMPLE VARIANCE	.086	.120	.076	.086	.076	.060	.059	.000	.138	.012	.180	.086	.026	.046	.069	.000
n REQUIRED FOR 95% CONFIDENCE	15	23	18	17	13	16	22	1	64	3	47	16	5	8	17	1
SAMPLE CONFIDENCE INTERVAL $\bar{x} \pm$	.078	.094	.085	.084	.071	.076	.165	.000	.132	.033	.137	.076	.046	.057	.081	.000

* 3-level task times are divided by 5-level times for each task. Then a sample of these factors are randomly selected to get the average task time increase factor for each work center.

σ^2 - the population variance

μ - the actual means of the treatment population

The first two are controllable but the latter two quantities are only estimates.

However, from Lindman we learn that the F-test is the most powerful, practical test of the H_o and reasonable estimates of the power can be made.[18] The estimate can then be used to determine how large an "n" will be needed for any specified significance level and power.

For example, let us compare the manhours for a given work center using normal skill levels and low skill levels assuming 25 manhours per unit time as the difference in mean time that needs to be detected. First, choose .05 as the significance level (α) and choose .9 as the desired probability of detecting such a difference (the power of the test). The number of observations (n) per group can then be estimated from Table A-10 in Lindman to be about 15 observations in each group.[19]

From this starting point one can make 15 simulation runs for each of the two groups in the analysis and calculate the sample variances to check the estimate of variances made previously. Now the number of simulation runs necessary to achieve the desired significance and power of the test can be recomputed.

The desired power and significance--say .9 and .05 respectively--can be seen as a tradeoff of variance and required number of simulation runs for the hypothetical work center of our example (see Figure 10).

Also one might note that the confidence limits for the actual mean values for each work center can be calculated from the equation

$$P \left[\bar{X} - \frac{b\,s}{\sqrt{n-1}} < \mu < \bar{X} \quad \frac{b\,s}{\sqrt{n-1}} \right] = 1 - \alpha$$

where

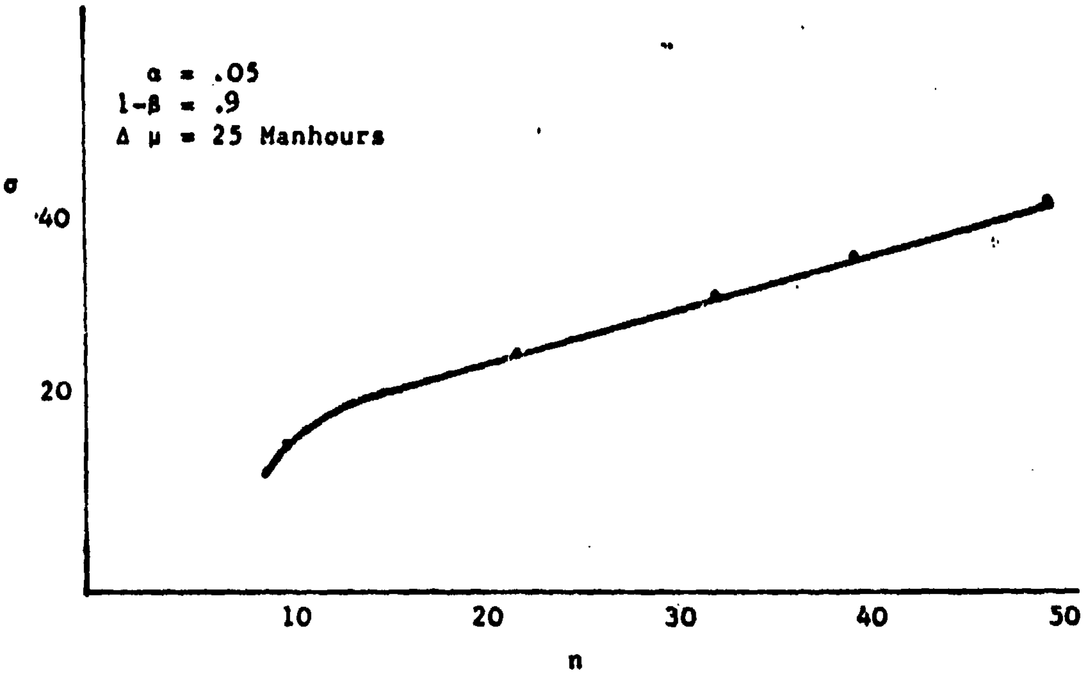
$\bar{X}$ = sample mean

s^2 = sample variance

n = number of observations in sample

b = number of standard deviations associated with

This calculation will be helpful to determine the magnitude of the effect of skill level changes within each work center.[20]



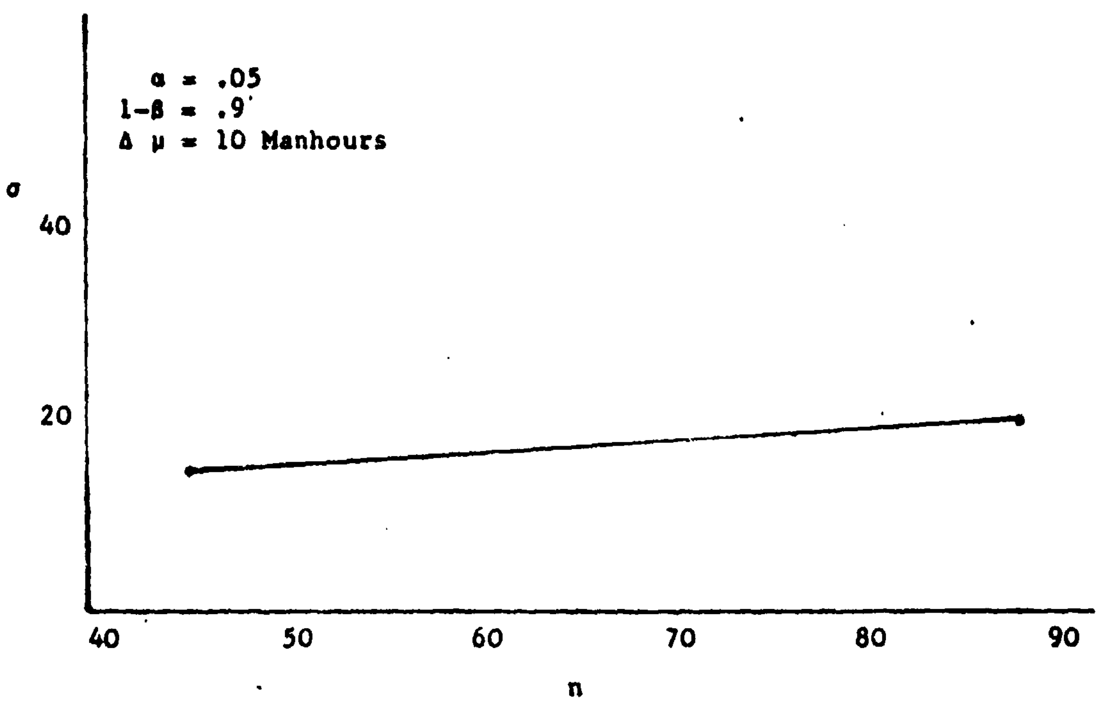


FIGURE 10. Variance Tradeoff.

CHAPTER III

ANALYSIS AND RESULTS

Task Time Comparisons

There are over 2000 total tasks and 28 different work centers (career designations or specialities which were chosen for this study) for the F-4E aircraft. For each of these tasks, elapsed time estimates were established through the operational audit technique for 5-level and 3-level maintenance personnel. Appendix C contains the times for all tasks for each skill level. Table 2 gives a listing of all work centers, the number of separate tasks for each work center, and the average ratio of 3-level divided by 5-level task time. The variances for sampled task times are also reproduced in Table 2.

Simulation Analysis

The output of the 5-level maintenance simulation runs appears in Table 3. This is series A in the experimental design. The output includes the average sorties/aircraft/day, the total maintenance manhours per flying hour, the maintenance manhours per flying hour for each work center, the average presortie and postsortie processing times. The mean figure for each category is calculated as well as

TABLE 2. Number of Tasks by Workcenter

WORK CENTER	Bomb Navigation 321X2	Automatic Flight Control 325X0	Instruments 325X1	Communications 328X0	Navigation 328X1	Electronic Warfare 328X3	Inertial Navigation 328X4	Sensors 329X0	Photographic 404X1	Electrical Systems 423X0	Environmental Systems 423X1	Egress 423X2	Fuel Systems 423X3	Pneudraulics 423X4	Aerospace Ground Equipment 423X5
NUMBER OF TASKS	195	57	208	59	75	67	76	35	33	152	52	52	85	169	33
$\bar{X}$ SAMPLE MEAN *	1.51	1.58	1.46	1.34	1.32	1.61	1.36	1.37	1.46	1.46	1.44	1.49	1.36	1.50	1.34
S^2 SAMPLE VARIANCE	.236	.074	.098	.114	.057	.160	.110	.115	.098	.098	.106	.081	.086	.120	.074

WORK CENTER	Jet Engines 426X2	Flightline Maintenance 431F1	Reclamation and Repair 431R1	Special Duties 431Y1	Munitions Maintenance 461X0	Gun Services 462X0	Weapons Loading 462L0	Weapons Release 462W0	Machine Shop 531X0	Metal Processing 531X1	Structural Repair 531X3	Corrosion Control 531X4	Non Destructive Inspection 531X5
NUMBER OF TASKS	41	218	92	8	10	33	19	40	141	53	144	21	26
$\bar{X}$ SAMPLE MEAN *	1.44	1.58	1.64	1.31	1.5	1.18	1.47	1.3	1.67	1.44	1.56	1.38	1.5
S^2 SAMPLE VARIANCE	.086	.074	.090	.059	.000	.138	.012	.180	.086	.076	.046	.069	.000

* $\bar{X}$ AVERAGE TIME INCREASE (3 Level Time divided by 5 Level Time)

TABLE 3. Results of 5-Level Baseline Simulation

WORK CENTER →	Sorties Per Aircraft/Day	Maintenance Manhour Per Flying Hour	Average Presortie Time	Average Postsortie Time	Bomb Navigation 32102	Automatic Flight Control 325X0	Instruments 325X1	Communications 328X0	Navigation 328X1	Electronic Warfare 328X3	Inertial Navigation 328X4	Sensors 329X0	Photographic 404X1	Electrical Systems 423X0	Environmental Systems 423X1	Egress 423X2
$\bar{X}$ SIMULATION MEAN *	2.284	37.66	1.87	6.12	3.13	.29	.66	.87	.46	1.55	.74	.05	.28	.63	.23	.24
S^2 SIMULATION VARIANCE	.003	12.01	.033	.047	.071	.003	.010	.015	.005	.027	.018	.001	.002	.008	.003	.002
$\hat{n}$ ESTIMATED SAMPLE SIZE REQUIRED **	1	4	1	1	4	17	11	10	11	2	16	249	10	9	28	21
$\bar{X}$ ADDITIONAL 50 DAY SIMULATION MEAN	2.33	37.26	1.80	6.10	3.12	.31	.62	.82	.42	1.48	.84	.05	.28	.60	.25	.25

WORK CENTER	Fuel Systems 423X3	Pneudraulics 423X4	Aerospace Ground Equipment 423X5	Jet Engines 426X2	Flightline Maintenance 431F1	Reclamation and Repair 431R1	Special Duties 431Y1	Munitions Maintenance 462X0	Gun Services 462G0	Weapons Loading 462L0	Weapons Release 462W0	Machine Shop 531X0	Metal Processing 531X1	Structural Repair 531X3	Corrosion Control 531X4	Non Destructive Inspection 531X5
$\bar{X}$ SIMULATION MEAN	1.46	.98	.19	5.16	4.81	1.01	.12	4.29	1.79	3.60	2.43	.33	.05	1.94	.01	.04
S^2 SIMULATION VARIANCE	.028	.026	.001	2.93	.024	.050	.002	.266	.030	.012	.057	.001	.000	.020	.000	.000
$\hat{n}$ ESTIMATED SAMPLE SIZE REQUIRED	7	13	17	52	1	23	63	2	5	1	2	6	44	4	580	63
$\bar{X}$ ADDITIONAL 50 DAY SIMULATION MEAN	1.48	.92	.19	4.53	4.71	.96	.13	4.21	1.93	3.54	2.56	.33	.04	1.82	.01	.05

* $\bar{X}$ is in hours for all entries except sorties per aircraft/day.
** Due to extremely small variance very few samples are required to be 95% confident that results lie within 10% of true mean value.

the variance and number of "runs" necessary to be 95 percent confident that the actual mean is within 10 percent of the simulation mean. The number of runs is calculated by the statistical technique previously described on page 41.[21]

These data come from 140 days of simulation. The first 90 days were used to calculate the variance and estimate the number of data points required to meet the confidence limits stated above. An autocorrelation program was also utilized to determine how many days need be simulated to constitute each independent data point. The autocorrelation effort demonstrated that any one simulation day is not statistically correlated with any preceding or following day. Due to the extremely large number of occurrences each simulation day, these results are intuitive.

The output of the 3-level simulation runs are presented in Table 4. This is experimental design series B. The same information is provided as for the 5-level maintenance simulation evaluation. For this simulation effort every task time has been evaluated and changed as necessary to account for the additional time required for low skilled (3-level) maintenance personnel.

Clearly there is a large difference in mission capability when low skilled maintenance is utilized. The most significant numbers to compare at this point relate to average sorties/aircraft/day and MMHPFH (76 percent as many sorties produced and 134 percent as many manhours used).

TABLE 4. Results of 3-Level Baseline Simulation

WORK CENTER →	Sorties Per Aircraft/Day	Maintenance Manhour Per Flying Hour	Average Presortie Time	Average Postsortie Time	Bomb Navigation 32102	Automatic Flight Control 325X0	Instruments 325X1	Communications 328X0	Navigation 328X1	Electronic Warfare 328X3	Inertial Navigation 328X4	Sensors 329X0	Photographic 404X1	Electrical Systems 423X0	Environmental Systems 423X1	Egress 423X2
$\bar{x}$ SIMULATION MEAN	1.76	49.66	2.93	8.44	3.66	.43	.92	1.32	.53	2.31	1.12	.06	.39	.81	.33	.30
S^2 SIMULATION VARIANCE	.022	27.7	.053	.908	.67	.046	.09	.21	.054	.303	.145	.006	.074	.048	.025	.018
n ESTIMATED SAMPLE SIZE REQUIRED	3	6	3	6	21	100	46	44	77	24	48	57	65	61	92	80
$\bar{x}$ ADDITIONAL 50 DAY SIMULATION MEAN	1.74	50.89	2.99	8.52	3.73	.44	.89	1.31	.52	2.26	1.02	.07	.43	.85	.30	.35

WORK CENTER	Fuel Systems 423X3	Pneudraulics 423X4	Aerospace Ground Equipment 423X5	Jet Engines 426X2	Flightline Maintenance 431F1	Reclamation and Repair 431R1	Special Duties 431Y1	Munitions Maintenance 462X0	Gun Services 462G0	Weapons Loading 462L0	Weapons Release 462W0	Machine Shop 531X0	Metal Processing 531X1	Structural Repair 531X3	Corrosion Control 531X4	Non Destructive Inspection 531X5
$\bar{x}$ SIMULATION MEAN	2.10	1.19	.27	5.22	7.17	1.72	.15	4.14	2.60	4.95	3.59	.42	.38	2.50	.02	.05
S^2 SIMULATION VARIANCE	.289	.280	.019	6.28	.642	.867	.013	1.62	.448	.210	.445	.029	.004	.327	.001	.002
n ESTIMATED SAMPLE SIZE REQUIRED	27	80	105	95	6	121	238	39	28	4	15	69	259	22	1826	276
$\bar{x}$ ADDITIONAL 50 DAY SIMULATION MEAN	2.13	1.29	.28	5.53	7.28	1.48	.13	4.39	2.39	5.08	3.89	.47	.08	2.65	.01	.05

See Table 5 for the comparison of each work center. Note that these are two extreme positions. The 5-level baseline situation stems from the assumption that all assigned maintenance personnel perform at the 5-level rate. The 3-level baseline situation comes from the assumption that all assigned maintenance personnel perform at the 3-level speed.

Having demonstrated a significant effect from utilizing 3-level maintenance, it is now necessary to find the simplest method to forecast these results without the need to perform a full operational audit for each aircraft weapon system. This leads to the experimental design series C.

By weighting average sample work center task time percent increase by the number of tasks within each work center, the overall average percent of task time increase when maintenance is performed by 3-level versus 5-level personnel is 149.4 percent. This percentage is developed as follows. We sample each work center to get an average percent task time increase for 3-level versus 5-level maintenance. Then we weight each work center's percent task time increase by the proportion of total tasks that fall within that work center. The result is an overall average task time increase factor of 1.494. Because we are anticipating further uses for our data a stratified sampling technique is used to collect. Now we multiply every task time in the original 5-level simulation program by 1.494 and then rerun the simulation. In LCOM this figure is

TABLE 5. Comparison of 3-Level and 5-Level Results

WORK CENTER →	Sorties Per Aircraft/Day	Maintenance Manhour Per Flying Hour	Average Presortie Time	Average Postsortie Time	Bomb Navigation [illegible]	Automatic Flight Control 325X0	Instruments 325X1	Communications 328X0	Navigation 328X1	Electronic Warfare 328X3	Inertial Navigation 328X4	Sensors 316X0	Photographic 404X1	Electrical Systems 423X0	Environmental Systems 423X1	Egress 423X2
5-LEVEL BASELINE SIMULATION RESULTS	2.31	37.46	1.84	6.11	3.13	.30	.64	.85	.44	1.52	.79	.05	.28	.62	.24	.25
3-LEVEL BASELINE SIMULATION RESULTS	1.75	50.28	2.96	8.50	3.70	.44	.91	1.32	.53	2.29	1.07	.065	.41	.83	.32	.33
3-LEVEL SIM. RESULTS / 5-LEVEL SIM. RESULTS	.76	1.34	1.61	1.39	1.18	1.47	1.42	1.55	1.20	1.51	1.35	1.30	1.46	1.34	1.33	1.32
SAMPLE % INCREASE					1.51	1.58	1.46	1.34	1.32	1.61	1.36	1.37	1.46	1.46	1.44	1.49

WORK CENTER	Fuel Systems 423X3	Pneudraulics 423X4	Aerospace Ground Equipment 423X5	Jet Engines 426X2	Flight Line Maintenance 431F1	Reclamation and Repair 431R1	Special [illegible] 431X1	Munitions Maintenance 462X0	Gun Services 462GG	Weapons Loading [illegible]	Weapons Release [illegible]	Machine Shop 531X0	Metal Processing 531X1	Structural Repair [illegible]	Corrosion Control [illegible]	Non Destructive Inspection [illegible]
5-LEVEL BASELINE SIMULATION RESULTS	1.47	.95	.19	4.85	4.76	.99	.13	4.25	1.86	3.57	2.50	.33	.05	1.86	.01	.05
3-LEVEL BASELINE SIMULATION RESULTS	2.12	1.24	.28	5.34	7.21	1.68	.14	4.31	2.49	5.02	3.73	.45	.08	2.57	.015	.05
3-LEVEL SIM. RESULTS / 5-LEVEL SIM. RESULTS	1.44	1.31	1.47	1.10	1.51	1.70	1.08	1.01	1.34	1.41	1.49	1.36	1.60	1.38	1.50	1.00
SAMPLE % INCREASE	1.56	1.50	1.34	1.44	1.38	1.64	1.31	1.50	1.18	1.47	1.30	1.62	1.44	1.56	1.38	1.50

Copy available to DTIC does not permit fully legible reproduction

called a TMULT (Task Time Multiplier). The results of this technique are presented in Table 6. Again the same confidence limits were used to determine the run lengths. We will make use of these stratified samples again when we consider data grouped by work center and other grouping methods.

Another, and more precise way to calculate an overall task time increase factor is to weight the average sampled work center task time percent increases by the average maintenance manhours per flying hour ratios from the 5-level simulation results. This additional weighting takes into account the number of times each particular work center performs maintenance, elapsed maintenance time, and crew size as well as the average task time increase for 3-level versus 5-level maintenance personnel.

The results of this method of averaging is an overall task time increase factor of 1.463. Table 6 also displays the results of using TMULT = 1.463.

Since both of the preceding TMULT calculations round off to 1.5 when using two place accuracy, Table 7 includes a TMULT factor of 1.5 to check the sensitivity of the LCOM simulation in relation to these different TMULT figures. From Table 7 note that these three TMULT value give nearly the same results.

Significant Differences

The term "significant difference" in the sense utilized for this study depends entirely upon which question is to be

TABLE 6. TMULT 1.494 and TMULT 1.463 Results

WORK CENTER →	Sorties Per Aircraft/Day	Maintenance Manhour Per Flying Hour	Average Presortie Time	Average Postsortie Time	Bomb Navigation	Automatic Flight Control	Instruments	Communications	Navigation	Electronic Warfare	Inertial Navigation	Sensors	Photographic	Electrical Systems	Environmental Systems	Egress
					321C0	[illegible]	325X1	328X0	[illegible]	328X3	328X4	326X6	424X1	423X0	423X1	423X2
TMULT 1-494 RESULTS	1.67	55.56	2.88	9.22	4.56	.41	.95	1.31	.60	2.23	1.10	.07	.47	.96	.38	.33
TMULT 1-494 RESULTS 5-LEVEL SIM. RESULTS	.72	1.48	1.57	1.51	1.46	1.37	1.42	1.54	1.36	1.47	1.39	1.40	1.66	1.55	1.58	1.32
TMULT 1.463 RESULTS	1.74	55.29	2.81	8.73	4.25	.46	.97	1.25	.62	2.30	1.13	.037	.47	.84	.32	.32
TMULT 1.463 RESULTS 5-LEVEL SIM. RESULTS	.75	1.48	1.53	1.43	1.36	1.53	1.52	1.47	1.41	1.51	1.42	.74	1.69	1.35	1.33	1.28

WORK CENTER	Fuel Systems	Pneudraulics	Aerospace Ground Equipment	Jet Engines	Flight Line Maintenance	Reclamation and Repair	Special Duties	Munitions Maintenance	Gun Services	Weapons Loading	Weapons Release	Machine Shop	Metal Processing	Structural Repair	Corrosion Control	Non Destructive Inspection
	423X3	423X4	423X5	426X2	431F1	431R1	431Y1	462X0	462G0	462L0	462R0	531X0	531X1	531X3	531X4	531X5
TMULT 1-494 RESULTS	2.20	1.42	.29	6.27	7.35	1.26	.15	6.23	2.86	5.28	3.91	.46	.06	3.13	.015	.07
TMULT 1-494 RESULTS 5-LEVEL SIM. RESULTS	1.50	1.49	1.53	1.29	1.56	1.27	1.15	1.47	1.54	1.46	1.56	1.39	1.20	1.68	1.50	1.40
TMULT 1.463 RESULTS	2.14	1.34	.26	7.05	7.10	1.40	.18	6.43	2.56	5.33	3.72	.50	.07	2.73	.015	.07
TMULT 1.463 RESULTS 5-LEVEL SIM. RESULTS	1.46	1.41	1.37	1.45	1.49	1.41	1.38	1.51	1.38	1.49	1.49	1.52	1.40	1.47	1.50	1.40

Copy available to DTIC does not permit fully legible reproduction

TABLE 7. COMPARISON OF TMULT RESULTS

WORK CENTER →	Sorties Per Aircraft/Day	Maintenance Manhour Per Flying Hour	Average Preventive Time	Average Preventive Time	Bomb Navigation 321X2	Automatic Flight Control 325X0	Instruments 325X1	Communications 328X0	Navigation 328X1	Electronic Warfare 328X3	Inertial Navigation 328X4	Sensors 329X0	Photographic 404X1	Electrical Systems 423X0	Environmental Systems 423X1	Egress 423X2
TMULT 1.50 RESULTS	1.69	55.04	2.87	8.94	4.59	.46	.99	1.25	.63	2.20	1.37	.07	.42	.92	.35	.38
TMULT 1.50 RESULTS 5-LEVEL SIM. RESULTS	.73	1.47	1.56	1.46	1.47	1.53	1.55	1.47	1.43	1.48	1.48	1.40	1.58	1.48	1.46	1.52
AVERAGE RESULT FROM TMULT 1.50,1.494,1.463	1.70	55.30	2.85	8.96	4.67	.44	.97	1.27	.62	2.24	1.33	.06	.45	.91	.35	.34
S^2 VARIANCE OF TMULT VALUES	.0004	.0451	.0009	.0403	.0236	.0006	.0003	.0008	.0002	.0018	.0006	.0002	.0006	.0025	.0006	.0067

	Fuel Systems 423X3	Pneudraulics 423X4	Aerospace Ground Equipment 423X5	Jet Engines 426X2	Flightline Maintenance 431F1	Reclamation and Repair 431E1	Special Duties 431X1	Munitions Maintenance 461X0	Gun Services 462X0	Weapons Loading 462X1	Weapons Release 462X0	Machine Shop 531X0	Metal Processing 531X1	Structural Repair 531X2	Corrosion Control 531X4	Non Destructive Inspection 531X5
TMULT 1.50 RESULTS	2.31	1.48	.31	5.89	7.25	1.30	.14	6.16	2.68	5.39	3.79	.53	.06	3.06	.02	.05
TMULT 1.50 RESULTS 5-LEVEL SIM. RESULTS	1.57	1.56	1.63	1.21	1.52	1.31	1.08	1.65	1.44	1.51	1.52	1.61	1.20	1.65	2.00	1.00
AVERAGE RESULT FROM TMULT 1.50,1.494,1.463	2.22	1.41	.29	6.40	7.23	1.32	.16	6.27	2.70	5.33	3.81	.50	.06	2.97	.017	.06
S^2 VARIANCE OF TMULT VALUES	.0050	.0033	.0004	.2337	.0106	.0035	.0003	.0131	.0152	.0020	.0062	.0008	.0000	.0304	.0000	.0001

answered. In terms of sorties/aircraft/day a difference of 10 percent or approximately .2 sorties/aircraft/day is considered highly significant and a difference of 5 percent or .1 sorties/aircraft/day is considered notable. This is a consensus from past LCOM studies. As can be observed in Tables 3 and 5, the sorties/aircraft/day do not significantly differ between 3-level baseline (Series B) and the three TMULT efforts (Series C).

In the case of maintenance manhours per flying hour (MMHPFH) management uses 5-10 percent as a significant difference. As explained previously, the "n" (number of simulation data points) required to be within 10 percent of the true mean is calculated. The "n" required to insure the power of the test to be at least .90 is also determined. In all cases the number of samples/simulation days meet both requirements. As can be seen in Tables 4, 6 and 7, the MMHPFH for the 3-level baseline (Series B) simulation effort does differ from the three TMULT simulation methods (these three methods do not significantly differ from each other) by nearly 10 percent. In all cases the TMULT methods require less average presortie preparation time but more postsortie time. We shall pursue this later.

Work Center Task Time Increase Factor

Before looking for an explanation to this "coincidence," the Series E section of the experimental design is analysed. Whereas the TMULT methods grouped all tasks irrespective of work center, this time we will consider each work center separately for the purpose of the simulation.

Multiplying all tasks within each work center by the average task time increase for the work center (as determined by the stratified sampling by work center) and rerunning the simulation effort produces the results in Table 8. Remember that we initially collected our samples by work centers and calculated the number of samples required from each work center to meet the 95 percent confidence restriction. We now apply the work center related factor to all task within the baseline 5-level simulation to produce our estimated 3-level output. The sorties/aircraft/day, and all of the work center maintenance manhours per flying hour are in line with the baseline 3-level (Series B) data. However, the difference in the total MMHPFH is significant.

Other Grouping Techniques

Now let us divide the work centers into groups and treat each group as we previously treated the work centers. For example, choosing three groups by comparing the average percent time increase for each work center. Then, using natural break points, we can divide the work centers into categories according to the task time increase factors. The difference in the task time increase factors can be grouped into small, moderate, and large difference categories. Each 5-level baseline task time is then multiplied by one of the three group task time increase factors from the following:

Small Difference		Moderate Difference		Large Difference	
328X0	1.34	321Q2	1.51	325X0	1.58
328X1	1.32	325X1	1.46	328X3	1.61
328X4	1.36	404X1	1.46	324X3	1.56
329X0	1.37	423X0	1.46	431F1	1.58
423X5	1.34	423X1	1.44	431R1	1.64
431Y1	1.31	423X2	1.49	531X0	1.62
462G0	1.18	423X4	1.50	531X3	1.56
462W0	1.30	462X2	1.44		
531X4	1.38	461X0	1.50		
		462L0	1.47		
		531X1	1.44		
		531X5	1.50		

The unweighted mean is then calculated for each category. All tasks for each category, as utilized in the 5-level baseline situation, are then multiplied by the respective task time increase factor.

A simulation was run utilizing this grouped work center technique. As can be seen in Table 8, the results are quite similar to those of the work center sampling technique. Again, the total MMHPFH result is significant.

In an effort to determine why the total MMHPFH for each sampling effort was larger than the total MMHPFH for the baseline 3-level simulation, this author discovered that the tasks for which the 5-level and 3-level times are similar are done more often than the tasks for which the 5-level and 3-level times differ greatly. When looked upon from another viewpoint this discovery becomes quite intuitive. Tasks which are performed more often, therefore being more repetitive or ordinary, lend themselves to being mastered sooner by the new 3-level maintenance personnel. Whereas tasks which are less repetitive (often longer, more involved

TABLE 8. RESULTS OF WORKCENTER SAMPLING TECHNIQUES

WORK CENTER →	Sorties Per Aircraft/Day	Maintenance Manhour Per Flying Hour	Average Presortie Time	Average Postsortie Time	Bomb Navigation 321X2	Automatic Flight Control 325X0	Instruments 325X1	Communications 328X0	Navigation 328X1	Electronic Warfare 328X3	Inertial Navigation 328X4	Sensors 329X0	Photographic 404X1	Electrical Systems 423X0	Environmental Systems 423X1	Egress 423X2
WORKCENTER SAMPLING SIMULATION RESULTS	1.73	54.39	2.81	8.73	4.86	.42	.91	1.11	.53	2.43	1.06	.07	.45	.90	.31	.30
WORK CTR SAM. RESULTS / 5-LEVEL SIM. RESULTS	.75	1.45	1.48	1.44	1.55	1.40	1.42	1.31	1.20	1.60	1.34	1.40	1.61	1.45	1.29	1.20
WORKCENTER GROUPED FACTORS RESULTS	1.77	53.65	2.79	8.54	4.52	.51	.95	1.07	.56	2.33	.95	.06	.40	.73	.31	.30
W/C GROUPED RESULTS / 5-LEVEL SIM. RESULTS	.77	1.48	1.53	1.43	1.44	1.70	1.48	1.26	1.27	1.53	1.20	1.20	1.43	1.18	1.29	1.20

	Fuel Systems 423X3	Pneudraulics 423X4	Aerospace Ground Equipment 423X5	Jet Engines 426X2	Flightline Maintenance 431F1	Reclamation and Repair 431R1	Special Duties 431Y1	Munitions Maintenance 461X0	Gun Services 462G0	Weapons Loading 462L0	Weapons Release 462W0	Machine Shop 531X0	Metal Processing 531X1	Structural Repair 531X2	Corrosion Control 531X4	Non Destructive Inspection 531X5
WORKCENTER SAMPLING SIMULATION RESULTS	2.25	1.44	.27	6.54	7.57	1.40	.17	6.03	2.32	5.35	3.37	.54	.08	2.83	.02	.06
WORK CTR SAM. RESULTS / 5-LEVEL SIM. RESULTS	1.53	1.52	1.42	1.34	1.59	1.41	1.31	1.42	1.25	1.50	1.35	1.64	1.60	1.52	2.00	1.20
WORKCENTER GROUPED FACTORS RESULTS	2.31	1.30	.24	7.14	7.54	1.52	.14	5.88	2.17	4.94	3.30	.51	.07	2.97	.015	.06
W/C GROUPED RESULTS / 5-LEVEL SIM. RESULTS	1.57	1.37	1.26	1.47	1.58	1.54	1.08	1.38	1.17	1.38	1.32	1.55	1.40	1.60	1.50	1.20

tasks) require more experience to be mastered. This is not saying that these particular tasks must be accomplished more often in order to be mastered, though that may sometimes be the case. Rather, the 5-level, due to his longevity, relative experience, and greater likelihood of having seen or performed this task more often, has gained the speed advantage over the newer 3-level.

For example, if task A (say refueling an airplane) is performed for each sortie the 3-level will quickly learn to be as proficient as the 5-level maintenance person. On the other hand, task B (say troubleshooting an electrical wiring problem), which may be performed only one each 1000 sorties, the 3-level may need much more time, on the average, than the 5-level maintenance person.

Let us now weight the sampled task by the relative "hits" that occurred in the 5-level simulation effort. That is to say, weight the task samples by the relative proportion of time that each task occurs. The simplest and quickest way to do this is to look at the output of the 5-level baseline simulation. From the "hit matrix" we can see the number of times each sampled task was performed in that simulation effort.

The average, weighted, task time increase factor for each work center can now be recomputed. When utilizing these factors (see Table 9) all parameters are in line with the 3-level baseline simulation. Once again we divide the

TABLE 9. Results of Simulation Using Weighted Task Times and Workcenter Sampling

WORK CENTER →	Sorties Per Aircraft/Day	Maintenance Manhour Per Flying Hour	Average Preflight Time	Average Postflight Time	Bomb Navigation 321X2	Automatic Flight Control 325X0	Instruments 325X1	Communications 328X0	Navigation 328X1	Electronic Warfare 328X3	Inertial Navigation 328X4	Sensors 329X0	Photographic 404X1	Electrical Systems 423X0	Environmental Systems 423X1	Egress 423X2
NEW TASK TIME MULTIPLICATION FACTORS					1.2	1.5	1.4	1.5	1.2	1.5	1.4	1.3	1.5	1.3	1.3	1.3
RESULTS OF SIMULATION	1.80	48.76	2.74	8.28	3.78	.45	.86	1.49	.52	2.33	1.06	.05	.45	.81	.34	.34
ORIGINAL WORKCENTER MULTIPLICATION FACTOR					1.18	1.47	1.42	1.55	1.20	1.51	1.35	1.30	1.46	1.34	1.33	1.32
CURRENT RESULTS 3-LEVEL BASELINE	1.03	.97	.93	.97	1.02	1.02	1.00	1.05	.98	1.02	.99	.83	1.09	.98	1.06	1.03

	Fuel Systems 423X3	Pneudraulics 423X4	Aerospace Ground Equipment 423X5	Jet Engines 426X2	Flightline Maintenance 431F1	Reclamation and Repair 431R1	Special Duties 431Y1	Munitions Maintenance 461X0	Gun Services 462G0	Weapons Loading 462L0	Weapons Release 462X0	Machine Shop 531X0	Metal Processing 531X1	Structural Repair 531X3	Corrosion Control 531X4	Non Destructive Inspection 531X5
NEW TASK TIME MULTIPLICATION FACTORS	1.4	1.3	1.5	1.1	1.5	1.6	1.0	1.0	1.3	1.4	1.5	1.4	1.4	1.4	1.4	1.5
RESULTS OF SIMULATION	1.96	1.25	.28	4.90	7.29	1.54	.10	4.38	2.24	4.97	3.94	.40	.08	2.66	.01	.04
ORIGINAL WORKCENTER MULTIPLICATION FACTOR	1.44	1.31	1.47	1.10	1.51	1.70	1.08	1.01	1.34	1.41	1.49	1.36	1.60	1.38	1.50	1.00
CURRENT RESULTS 3-LEVEL BASELINE	.93	1.01	1.00	.92	1.01	.92	.71	1.02	.90	.99	1.06	.89	1.00	1.04	1.00	.80

work centers into groups. This time, since there are no groups with a factor greater than 1.6, use two categories. Weight the factors by the number of "hits" as described previously. This yields 1.25 as a TMULT for all work centers that had a task time increase multiplication factor less than 1.35 in Table 9, and 1.50 as a TMULT for all work centers with a weighting factor greater than 1.35. The results are presented in Table 10. One can also recompute the overall TMULT factor using this weighted sampling technique.

The results of rerunning the Series C simulation effort with TMULT = 1.35 (see Table 11), verify that the four parameters all meet the established significance criterion (that is, no significant difference between Series C and Series B).

Thus each of the three methods that utilize the final weighting technique produce the same results in terms of sortie rate and maintenance manhours per flying hour. However, some of the individual work centers do not remain within the 10 percent guide in terms of MMHPFH. Before analyzing this individual work center difference, the current results are summarized.

Depending upon what question one is seeking to answer one can now select the sampling technique that best resolves the problem. If one wishes to know only the change in expected sorties/aircraft/day, a simple random sample of size "n", when $n = [\frac{t\ s}{a\ \bar{X}}]^2$ as defined previously, will suffice to determine the TMULT factor, which can then be used to

TABLE 10. Results of Grouped Workcenter Sampling (with Weighted Task Times)

WORK CENTER	Sorties Per Aircraft/Day	Maintenance Manhour Per Flying Hour	Average Presortie Time	Average Postsortie Time	Bomb Navigation 321X2	Automatic Flight Control 325X0	Instruments 325X1	Communications 328X0	Navigation 328X1	Electronic Warfare 328X2	Inertial Navigation 328X4	Sensors 329X0	Photographic 404X1	Electrical Systems 423X0	Environmental Systems 423X1	Egress 423X2
WORK CENTER MULTIPLICATION FACTOR					1.25	1.5	1.5	1.5	1.25	1.5	1.5	1.25	1.5	1.25	1.25	1.25
NEW GROUPED WORKCENTER SIMULATION RESULTS	1.82	51.65	2.67	8.22	3.98	.48	1.00	1.41	.60	2.29	1.25	.05	.48	.81	.33	.34
ORIGINAL WORKCENTER MULTIPLICATION FACTOR					1.18	1.47	1.42	1.55	1.20	1.51	1.35	1.30	1.46	1.34	1.33	1.32
CURRENT RESULTS 3-LEVEL BASELINE	1.04	1.03	.90	.97	1.08	1.09	1.09	1.07	1.13	1.00	.93	.83	1.17	.98	1.03	1.03

	Fuel Systems 423X3	Pneudraulics 423X4	Aerospace Ground Equipment 423X5	Jet Engines 426X2	Flightline Maintenance 431F1	Reclamation and Repair 431R1	Special Duties 431Y1	Munitions Maintenance 461X0	Gun Services 462G0	Weapons Loading 462L0	Weapons Release 462W0	Machine Shop 531X0	Metal Processing 531X1	Structural Repair 531Y3	Corrosion Control 531X4	Non Destructive Inspection 531Y5
WORK CENTER MULTIPLICATION FACTOR	1.5	1.25	1.5	1.25	1.5	1.5	1.25	1.25	1.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5
NEW GROUPED WORKCENTER SIMULATION RESULTS	2.12	1.11	.30	5.23	7.18	1.55	.12	4.40	2.44	5.36	3.74	.49	.07	2.84	.01	.04
ORIGINAL WORKCENTER MULTIPLICATION FACTOR	1.44	1.31	1.47	1.10	1.51	1.70	1.08	1.01	1.34	1.41	1.49	1.36	1.60	1.38	1.50	1.00
CURRENT RESULTS 3-LEVEL BASELINE	1.00	.90	1.07	.98	1.00	.92	.86	1.02	.98	1.07	1.00	1.09	.88	1.10	1.00	.80

TABLE 11. RESULTS OF TMULT = 1.35 SIMULATION

WORK CENTERS	Sorties Per Aircraft/Day	Maintenance Manhour Per Flying Hour	Average Presortie Time	Average Postsortie Time	321Q2 Bomb Navigation	325X0 Automatic Flight Control	325X1 Instruments	328XC Communications	328X1 Navigation	328X3 Electronic Warfare	328X4 Inertial Navigation	329X0 Sensors	404X1 Photographic	423X0 Electrical Systems	423X1 Environmental Systems	423X2 Egress
RESULTS OF TMULT=1.35 SIMULATION	1.81	48.81	2.54	7.97	4.22	.42	.89	1.26	.62	1.95	1.17	.04	.37	.89	.40	.36
TMULT=1.35 RESULTS 5-LEVEL BASELINE	.78	1.30	1.37	1.30	1.23	1.35	1.39	1.42	1.41	1.28	1.48	1.00	1.32	1.44	1.47	1.44
TMULT=1.35 RESULTS 3-LEVEL BASELINE	1.03	.97	.86	.92	1.14	.95	.98	.95	1.17	.85	1.09	.62	.90	1.07	1.25	1.09
WITHIN ACCEPTABLE 3-LEVEL($\bar{X} \pm .1\bar{X}$)	YES	YES	NO	YES	NO	YES	YES	YES	NO	NO	YES	NO	YES	YES	NO	YES

	423X3 Fuel Systems	423X4 Pneudraulics	423X5 Aerospace Ground Equipment	426X2 Jet Engines	431F1 Flightline Maintenance	431R1 Reclamation and Repair	431Y1 Special Duties	461XC Munitions Maintenance	462C0 Gun Services	462L0 Weapons Loading	462W0 Weapons Release	531X0 Machine Shop	531X1 Metal Processing	531X3 Structural Repair	531X4 Corrosion Control	531X5 Non Destructive Inspection
RESULTS OF TMULT=1.35 SIMULATION	1.91	1.27	.27	4.97	6.37	1.19	.13	5.52	2.55	4.74	3.23	.48	.05	2.64	.01	.06
TMULT=1.35 RESULTS 5-LEVEL BASELINE	1.30	1.34	1.42	1.02	1.34	1.37	1.00	1.30	1.37	1.33	1.29	1.45	1.00	1.42	1.00	1.20
TMULT=1.35 RESULTS 3-LEVEL BASELINE	.90	1.02	.96	.93	.88	.71	.93	1.28	1.02	.94	.83	1.07	.63	1.03	1.00	1.20
WITHIN ACCEPTABLE 3-LEVEL ($\bar{X} \pm .1\bar{X}$)	YES	YES	YES	YES	NO	NO	YES	NO	YES	YES	NO	YES	NO	YES	YES	NO

resolve the question to the desired accuracy. If one wishes to know the effect a skill level change has upon total maintenance manhours per flying hour he needs to weight the samples by the number of hits from a current 5-level simulation run. If he wishes to know the effect upon average presortie or postsortie preparation time, the same method will work. However, if we wish to know the effect upon maintenance manhours per flying hour per work center we must use a stratified sampling method in conjunction with the "hit matrix" from the 5-level simulation. For the last problem group the work centers into two or more groups and then use a different multiplication factor for each.

CHAPTER IV

ANALYSIS AND RESULTS WITH LIMITED MANPOWER

The Constraining Process

The most important question remains, "what effect upon mission accomplishment results from a reduction of aircraft maintenance personnel skill levels?" Up to this time there has been no mention of a restriction upon the number of personnel in the maintenance work centers. Indeed, the assumption has been unlimited manning. This is, whenever the simulation program called for maintenance personnel, they were available. There were no queuing problems.

Tables 12 through 17 will present the constrained (limited manpower) data in the following way:

TABLE	FIG. 8 SERIES	SORTIES/AIRCRAFT/DAY	MMHPFH	WORK CENTER MAN/DEV.	SKILL LEVEL
12,14	A	2.2	37	210	5
13,14	B	1.8	49	274	3
15	C	1.8	49	274	3
16	D	1.8	49	274/0	3
17	E	1.8	51	274/0	3

This flow plan is the same as described in Figure 8 and used for the unconstrained manpower model.

We will follow the same process to determine the constrained manning situation as we did in Chapter III with the unlimited manning situation. First, we will limit the manning available in the 5-level baseline simulation to establish a constrained baseline. This is series A'. Then we will limit the manning available to the 3-level baseline model which use 100 percent operational audit task time data. This is series B'. From here we will proceed with averaging, sampling and grouping techniques to determine the feasibility of using a simplified technique to reproduce the results of series B'. As in Chapter III we will again compare sorties/aircraft/day and MMHPFH but in addition we must include a comparison of the manning package broken down by work centers.

This manning package is essential since we must be prepared to analyse the expected differences in mission accomplishment as a result of skill level changes. The expected sortie rate and manpower deviation for each specialty are of utmost importance to the decision maker in planning for various contingincies.

With limited manning the maintenance organization can not achieve its maximum sortie rate. It is common practice to use LCOM to determine the minimum manning package that will allow achievement of 95 percent of the sortie rate that is possible with unlimited manning. As explained in the LCOM manual, the available manning is limited in an iterative fashion until the minimum manning, by work center, is determined. That is, the minimum manning that will produce the required results as defined in the desired scenario.

In the case of an F-4E model we initially reduce the manning in each work center by reference to the matrix output (see page 21, Figure 7 for an example matrix) for the appropriate work. The objective is to assign a limited number of personnel to each work center while still achieving a high sortie rate. To achieve this the LCOM analyst observes how many maintenance specialists were used in the unconstrained simulation runs. The analyst further notes how often particular numbers of specialists were required for the subject work center. The analyst then subjectively assign the number of specialists to be available to that work center for the following simulation run. While allowing some maintenance tasks to be back ordered (that is, to wait until the required specialist(s) is available) the overall effect should not cause the loss of a significant number of sorties.

The analyst does the same type of analysis for each work center to establish the initial constrained manning package estimate. The simulation model is then rerun and the result observed. The overall sortie rate and the manpower matrix (now augmented by a manpower back order matrix) for each work center are again analyzed.

Once again the LCOM analyst studies these simulation outputs and establishes a new manpower package. Thus the manpower package is progressively changed and fine tuned until the analyst is convinced that the minimum manning has been achieved for each work center.

This iterative approach to manpower constraining often requires one or more man months to achieve. This constraining effort was separately performed upon our 5-level and our 3-level models. If, for 5-level, this manning package is 210 people for a normal LCOM analysis (this is only the direct labor force per shift for the work centers that are displayed - see Table 12), can one now expect to get 75 percent as many sorties accomplished in a given time period by using 210 3-level maintenance personnel? The answer is no, even assuming no safety or other problems to prevent the 3-level maintenance personnel from performing any task. Due to the additional queuing problems, since longer task times will create even longer aircraft wait-for-service times, the actual accomplishments well be far less than 95 percent of the unconstrained 3-level situation.

Thus, we increase the assigned manning or decrease our expectations in terms of sortie rate achievement. See Table 13 for the results of this 3-level constraining effort.

One further area needs to be discussed. That is the situation of minimum crew manning. Due to the numerous different specialities in the Air Force maintenance organization, certain work centers do not have enough work to keep their personnel busy. These work centers still require a

TABLE 12. 5-LEVEL BASELINE UNCONSTRAINED/CONSTRAINED MANNING

WORK CENTER →	Sorties Per Aircraft/Day	Maintenance Manhour Per Flying Hour	Average Preroute Time	Average Postroute Time	321Q2 Bomb Navigation	325X0 Automatic Flight Control	325X1 Instruments	328X0 Communications	328X1 Navigation	328X3 Electronic Warfare	328X4 Inertial Navigation	329X0 Sensors	404X1 Photographic	423X0 Electrical Systems	423X1 Environmental Systems	423X2 Egress
5-LEVEL BASELINE SIMULATION RESULTS	2.31	47.46	1.84	6.11	3.13	.30	.64	.85	.44	1.52	.79	.05	.28	.62	.24	.25
UNCONSTRAINED MANNING					18	6	10	10	7	16	9	2	4	8	6	5
CONSTRAINED MANNING (210 TOTAL)					15	4	6	6	4	9	6	(2)	(2)	6	3	(2)
5-LEVEL CONSTRAINED SIMULATION RESULTS	2.18	37.37	2.13	6.60	3.00	.27	.69	.87	.47	1.41	.86	.04	.32	.69	.24	.25

	423X3 Fuel Systems	423X4 Pneudraulics	423X5 Aerospace Ground Equipment	426X2 Jet Engines	431F1 Flightline Maintenance	431R1 Reclamation and Repair	431Y1 Special Duties	461X0 Munitions Maintenance	462G0 Gun Services	462L0 Weapons Loading	462W0 Weapons Release	531X0 Machine Shop	531X1 Metal Processing	531X2 Structural Repair	531X4 Corrosion Control	531X5 Non Destructive Inspection
5-LEVEL BASELINE SIMULATION RESULTS	1.47	.95	.19	4.85	4.76	.99	.13	4.25	1.86	3.57	2.50	.33	.05	1.86	.01	.05
UNCONSTRAINED MANNING	10	12	4	28	28	9	4	28	21	28	23	5	2	16	2	2
CONSTRAINED MANNING	8	6	2	21	22	6	(2)	20	10	16	14	(2)	(2)	10	(2)	(2)
5-LEVEL CONSTRAINED SIMULATION RESULTS	1.52	.95	.20	4.60	.13	.83	.13	3.97	1.92	3.53	2.66	.30	.45	1.86	.01	.05

( ) = Minimum Manning

Copy available to DTIC does not permit fully legible reproduction

TABLE 1?. 3-LEVEL BASELINE UNCONSTRAINED/CONSTRAINED MANNING

WORK CENTER →	Sorties Per Aircraft/Day	Maintenance Manhour Per Flying Hour	Average Preeorttle Time	Average Postsortie Time	Bomb Navigation 321O2	Automatic Flight Control 325X0	Instruments 325X1	Communications 328X0	Navigation 328X1	Electronic Warfare 328X3	Inertial Navigation 328X[illegible]	Sonar 329X0	Photographic 404X1	Electrical Systems 423X[illegible]	Environmental Systems 423X1	Rerage [illegible]
3-LEVEL BASELINE SIMULATION RESULTS	1.76	49.13	2.12	8.46	3.70	.49	.99	1.12	.51	2.25	1.05	.05	.41	.86	.28	.36
UNCONSTRAINED MANNING					25	8	14	16	8	27	11	4	7	13	6	8
CONSTRAINED MANNING (274 TOTAL)					18	4	6	8	4	14	7	(2)	3	8	4	4
3-LEVEL CONSTRAINED SIMULATION RESULTS	1.57	49.28	2.91	8.80	3.92	.46	.94	1.20	.56	2.34	1.01	.09	.48	.86	.32	.36

	Fuel Systems 423X3	Pneudraulics 423X4	Aerospace Ground Equipment 423X5	Jet Engines 426X2	Flightline Maintenance 431F1	Reclamation and Repair 431R1	Special Duties 431Y1	Munitions Maintenance 461X0	Gun Services 462C0	Weapons Loading 462L0	Weapons Release 462W0	Machine Shop 531X0	Metal Processing 531X1	Structural Repair 531X3	Corrosion Control 531X4	Non Destructive Inspection 531X5
3-LEVEL BASELINE SIMULATION RESULTS	2.74	1.40	.31	4.88	7.17	1.79	.18	4.35	2.47	5.01	3.62	.50	.07	2.47	.01	.36
UNCONSTRAINED MANNING	13	16	7	32	47	15	7	41	37	44	29	7	3	25	1	3
CONSTRAINED MANNING	10	9	3	22	30	8	4	24	18	24	18	4	(2)	14	(2)	(2)
3-LEVEL CONSTRAINED SIMULATION RESULTS	2.02	1.21	.30	4.81	7.08	1.59	.11	3.93	2.56	4.98	3.75	.43	.09	2.60	.00	.05

( ) = Minimum Manning

minimum crew to be on duty at all times during a maximum sortie generation effort. However, the actual workload in these work centers can be varied greatly without affecting the required manning. The work centers that have "minimum crew size manning" are indicated in Tables 12 and 13.

However, from these tables it is clear that the minimum manning package required to achieve 95 percent of the unconstrained 3-level accomplishment is far greater (274 manpower) than that of the 5-level baseline situation (210 manpower). It requires about 30 percent additional 3-level manning to achieve 75 percent of the 5-level accomplishment. If we were to constrain the 5-level manning to get the same achievement as the maximum 3-level capability we would need only 160 5-level personnel to accomplish the same sortie rate as infinite 3-level personnel (see Table 14). To get these results we constrain the 3-level baseline simulation to the point where the loss of one more specialist in any work center will result in less than the maximum sortie rate. The we constrain the 5-level baseline simulation model until we get the same sortie rate as the maximum 3-level effort.

We have developed a method whereby we can forecast the expected effect, in terms of sortie rate, total maintenance manhours, and total manning of a complete reduction of the maintenance force skill level. Next we will tackle the manning problem in terms of specialities (work centers).

TABLE 14. 5-LEVEL/3-LEVEL MANNING REQUIREMENTS FOR SAME ACCOMPLISHMENT

WORK CENTER	Sorties Per Aircraft/Day	Maintenance Manhour Per Flying Hour	Average Presortie Time	Average Postsortie Time	Bomb Navigation 321X2	Automatic Flight Control 325X0	Instruments 325X1	Communications 328X0	Navigation 328X1	Electronic Warfare 328X3	Inertial Navigation 328X4	Sensors 329X0	Photographic 404X1	Electrical Systems 423X0	Environmental Systems 423X1	Egress 423X2
5-LEVEL C-1 RESULTS	1.77	38.19	2.09	9.27	3.04	.31	.78	.79	.43	1.53	.97	.04	.27	.59	.12	.22
MANNING (160 TOTAL)					12	2	4	4	2	6	4	2	2	2	2	2
3-LEVEL LIGHTLY CONSTRAINED RESULTS	1.76	49.13	2.12	8.46	3.70	.49	.99	1.12	.51	2.25	1.05	.05	.41	.86	.28	.36
MANNING (374 TOTAL)					22	6	10	12	6	21	9	4	5	8	4	6

WORK CENTER	Fuel Systems 423X3	Pneudraulics 423X4	Aerospace Ground Equipment 423X5	Jet Engines 426X2	Flight Line Maintenance 431F1	Reclamation and Repair 431R1	Special Duties 431Y1	Munitions Maintenance 461X0	Gun Services 462G0	Weapons Loading 462L0	Weapons Release 462X0	Machine Shop 531X0	Metal Processing 531X1	Structural Repair 531X3	Corrosion Control 531X4	Non Destructive Inspection 531X5
5-LEVEL C-1 RESULTS	1.49	1.01	.22	5.44	4.97	.96	.09	4.08	1.66	3.56	2.39	.34	.05	1.86	.01	.06
MANNING (160 TOTAL)	6	4	1	16	20	4	2	15	9	13	10	2	2	8	2	2
3-LEVEL LIGHTLY CONSTRAINED RESULTS	2.34	1.40	.31	4.48	7.17	1.79	.18	4.35	2.47	5.01	3.62	.50	.07	2.47	.01	.09
MANNING (374 TOTAL)	12	14	5	26	36	12	6	32	28	36	24	5	2	19	2	2

*C-1 Results = $\bar{X}$ mean value results for constraint that matches 3-level constrained results

Copy available to DTIC does not permit fully legible reproduction

We now wish to determine whether sampling techniques can be utilized to determine the manning levels for each of the work centers. We will utilize the 3-level baseline, the weighted work center sampling model, the weighted and grouped work center sampling model, and the TMULT = 1.35 model. These models are of interest because they each produced the same sortie rate and total MMHPFH.

When we constrain the TMULT = 1.35 model we get the manning results found in Table 15. Although the total MMHPFH and sortie rates are similar to the results of the 3-level baseline simulation, both the total manning and the individual work centers show variations. Obviously, the use of a TMULT technique can be used for sortie rate and total MMHPFH determination but not for precise manning analysis.

Let us next work with the weighted work center sampling method. Constraining this model we get precisely the same results as we got from the 3-level baseline model (see Table 16). That is, we get the same manning package, the same sortie rate, and the same total MMHPFH. Clearly then, use of this technique will determine the effect of maintenance skill level changes.

Let us now redefine our work centers in such a way as to minimize the numbers of categories, and thus the number of samples required for our desired accuracy, that will still produce the same sortie rate, total MMHPFH, and manning package. We know that grouping our work centers into one

TABLE 15. THULT = 1.35 UNCONSTRAINED/CONSTRAINED RESULTS

WORK CENTER	Sorties Per Aircraft/Day	Maintenance Manhours Per Flying Hour	Average Preflight Time	Average Postflight Time	321C2 Bomb Navigation	325X0 Automatic Flight Control	325X1 Instruments	328X0 Communications	328X1 Navigation	328X2 Electronic Warfare	328X4 Inertial Navigation	324XC Sensors	404X1 Photographic	423X0 Electrical Systems	423X1 Environmental Systems	423X2 Egress
THULT = 1.35 UNCONSTRAINED SIM RESULTS	1.81	48.81	2.45	7.97	4.22	.42	.89	1.26	.62	1.95	1.17	.04	.37	.89	.40	.36
UNCONSTRAINED MANNING					30	7	13	14	8	20	12	4	7	10	9	6
CONSTRAINED MANNING					18	4	6	8	4	10	6	2	2	5	4	3
THULT = 1.35 CONSTRAINED SIM RESULTS	1.72	51.21	2.62	6.51	4.10	.40	.90	1.27	.59	2.12	1.15	.08	.47	.78	.33	.29

WORK CENTER	423X3 Fuel Systems	423X4 Pneudraulics	423X5 Aerospace Ground Equipment	426X2 Jet Engines	431F1 Flightline Maintenance	431R1 Reclamation and Repair	431Y1 Special Duties	462X0 Munitions Maintenance	462G0 Gun Services	462L0 Weapons Loading	462W0 Weapons Release	531XC Machine Shop	531X1 Metal Processing	531X3 Structural Repair	531X4 Corrosion Control	531X5 Non Destructive Inspection
THULT = 1.35 UNCONSTRAINED SIM RESULTS	1.91	1.27	.27	4.87	6.37	1.19	.13	5.52	2.55	4.74	3.23	.48	.05	2.64	.01	.06
UNCONSTRAINED MANNING	16	13	6	40	42	22	4	45	32	41	30	7	4	24	2	3
CONSTRAINED MANNING	10	9	2	22	28	8	2	24	16	24	16	3	2	12	2	2
THULT = 1.35 CONSTRAINED SIM RESULTS	2.12	1.36	.24	6.42	6.67	1.22	.17	5.62	2.46	4.81	3.40	.45	.06	2.58	.02	.07

TABLE 16. WEIGHTED WORKCENTER SAMPLING UNCONSTRAINED/CONSTRAINED RESULTS

WORK CENTER →	Sorties Per Aircraft/Day	Maintenance Manhour Per Flying Hour	Average Presortie Time	Average Postsortie Time	Bomb Navigation 321C2	Automatic Flight Control 325X0	Instruments 325X1	Communications 328X0	Navigation 328X1	Electronic Warfare 328X3	Inertial Navigation 328X4	Sensors 329X0	Photographic 404X1	Electrical Systems 423X0	Environmental Systems 423X1	Egress 423X2
WEIGHTED WORKCENTER SAMPLING RESULTS	1.80	48.76	2.74	8.28	3.78	.50	.86	1.49	.52	2.33	1.06	.04	.45	.81	.34	.34
UNCONSTRAINED					30	8	13	16	11	22	12	4	6	12	6	6
CONSTRAINED					18	4	6	8	4	14	7	(2)	3	6	4	4
DIFFERENCE IN MANNING FROM BASELINE					0	0	0	0	0	0	0	0	0	0	0	0

	Fuel Systems 423X3	Pneudraulics 423X4	Aerospace Ground Equipment 423X5	Jet Engines 426X2	Flightline Maintenance 431F1	Reclamation and Repair 431R1	Special Duties 431X1	Munitions Maintenance 461X0	Gun Services 462X0	Weapons Loading 462L0	Weapons Release 462W0	Machine Shop 531X0	Metal Processing 531X1	Structural Repair 531X3	Corrosion Control 531X4	Non Destructive Inspection 531X5
WEIGHTED WORKCENTER SAMPLING RESULTS	1.96	1.25	.28	4.40	7.29	1.34	.10	4.38	2.24	4.97	3.94	.40	.08	2.66	.01	.04
UNCONSTRAINED	15	16	4	26	44	19	5	39	27	41	33	8	3	26	2	2
CONSTRAINED	10	9	3	22	30	8	4	24	18	24	18	4	(2)	14	(2)	(2)
DIFFERENCE IN MANNING FROM BASELINE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

( ) = Minimum Manning

Copy available to DTIC does not permit fully legible reproduction

category will not work (this was our TMULT = 1.35 effort), so let us proceed with two categories.

One simple method to group the work centers is to divide them into two categories as defined on page 61. All of the work centers with weighted sample average task time increases of less than 1.35 are multiplied by the common factor 1.25. All those work centers with weighted sample average task time increases greater than 1.35 are multiplied by the common factor 1.50.

Constraining this model produces the results found in Table 17. As can be seen in Table 17, this technique produces the same manning package and sortie rate as the 3-level baseline simulation model. Therefore, this sampling technique is an acceptable substitute that will give the sortie rate and manning differences between 5-level and 3-level maintenance manning for the F-4E aircraft.

Qualifications and Limitations

This study has produced a method that can be utilized to estimate the effect of a skill level change. The use of the F-4E aircraft has been only an example. All work centers were not included in the tables. Some were so small that minimum manning was obviously sufficient. Phase inspection was not included since it was assumed that these tasks would be deferred during the period of surge effort. Other unscheduled maintenance was not assumed to be deferrable. Only one type of mission was utilized in this study but

TABLE 17. WEIGHTED SAMPLING BY TWO CATEGORIES

WORK CENTER →	Sorties Per Aircraft/Day	Maintenance Manhour Per Flying Hour	Average Presortie Time	Average Postsortie Time	Bomb Navigation 321X0	Automatic Flight Control 325X0	Instruments 325X1	Communications 328X0	Navigation 328X1	Electronic Warfare 328X3	Inertial Navigation 328X4	Sensors 329X0	Photographic 404X1	Electrical Systems 423X0	Environmental Systems 423X1	Egress 423X2
SIMULATION RESULTS	1.82	51.65	2.67	8.22	3.98	.49	1.00	1.41	.43	2.29	1.25	.05	.45	.81	.33	.34
UNCONSTRAINED MANNING					28	8	13	17	13	21	13	4	6	13	7	6
MANNING REQUIRED					18	4	6	8	4	14	7	2	3	6	4	4
DIFFERENCE IN MANNING FROM BASELINE					0	0	0	0	0	0	0	0	0	0	0	0

	Fuel Systems 423X3	Pneudraulics 423X4	Aerospace Ground Equipment 423X5	Jet Engines 426X2	Flightline Maintenance 431F1	Reclamation and Repair 431F1	Special Duties [illegible]	Munitions Maintenance 461X0	Gun Services [illegible]	Weapons Loading [illegible]	Weapons Release [illegible]	Machine Shop 531X0	Metal Processing 531X1	Structural Repair 531X3	Corrosion Control 531X4	Non Destructive Inspection 531X5
SIMULATION RESULTS	2.12	1.11	.30	5.23	7.18	1.35	.12	5.40	2.14	5.36	3.74	.49	.07	3.04	.01	.04
UNCONSTRAINED MANNING	16	12	5	33	46	17	5	42	27	48	29	10	4	28	3	3
MANNING REQUIRED	10	9	3	22	30	8	4	24	18	24	18	4	2	14	2	2
DIFFERENCE IN MANNING FROM BASELINE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

others could be incorporated without model changes. The shift manning levels produced in this study are not presented as the optimal situation but rather for comparison of 5-level and 3-level output potential under the simplified hypothetical scenario described.

Although every work center and each work unit code (WUC) task were included in the operational audit, the task times that were developed are subjective opinions of maintenance specialists and supervisors. These times represent the hypothetical "average 5-level" and "average 3-level," and do not consider the additional problems of extenuating circumstances. The standard deviation for all tasks is assumed to be a constant percent of the mean task time. Weather, climate, enemy activity, spare parts shortage, Production Oriented Maintenance Organization, multiple aircraft types, morale, deployment location, and possibly other relevant factors have not been included in this study.

The time required for a 3-level maintenance specialist to upgrade to a 5-level may change drastically in wartime due to the accelerated rate of activity. This upgrade time may also be highly work center related. The complexity of the particular weapon system or subsystem may greatly affect the relative productivity of a 5-level versus a 3-level maintenance specialist.

Summary of Simulation Analysis

From the 5-level baseline model, we have the unconstrained sortie rate accomplishment and related manning/manhours. We also have the manning necessary to achieve 95 percent of the unconstrained sortie rate and the manning required to achieve the same sortie rate as with the unconstrained baseline 3-level model. See Tables 12, 13, and 14 respectively.

From the 3-level baseline model, we have the unconstrained sortie rate and related manning/manhours. We also have the manning required to achieve 95 percent of the 3-level baseline sortie rate.

For the TMULT (all maintenance tasks multiplied by a common factor) effort that most closely duplicates the 3-level baseline results, we have the unconstrained and constrained results as well as the required manning comparisons (see Table 15).

We also have results from individual work center sampling and from grouped work center sampling efforts. For each of these (see Tables 16 and 17), we have the same information as for the other methods above.

The 3-level individual work center sampling, and grouped work center sampling models require the same manning in each work center. Thus the sampling technique, whereby the work centers are divided in two categories, will suffice to estimate the effect of the skill level difference upon manning.

We have now considered the situation with all 5-level or with all 3-level maintenance. But it is more likely that we shall have a maintenance situation that has some combination of maintenance skills. With the techniques that we have developed we now address this problem. Chapter V is devoted to an analysis of mixed skill levels and management policies.

CHAPTER V

5-LEVEL/3-LEVEL MIXTURE ANALYSIS

It is necessary to first define low maintenance personnel will be utilized. If we have half 5-level and half 3-level personnel doing the jobs, we could have maintenance crews made up of all 5-level, all 3-level, or a combination of each. From the operational audit interviews we learn that, after initial checkout, generally the task times for crews that include at least one 5-level are the same as for crews that include all 5-level personnel. We must define our average maintenance crew skill level for the simulation method that we are undertaking. If, for example, the probability that a maintenance crew for any particular task will include at least one 5-level (or above) is 50%, then the average performance level of the maintenance shop is halfway between the 5 and 3 level.

The probability that a maintenance crew would include at least one 5-level or above would be determined by the particular maintenance mix available and the management decisions that pertain to manpower useage. If, for the sake of argument, we assume that one-fifth of the 3-level maintenance personnel are in need of training in any particular task, we must consider one-fifth of the tasks that are being led by a 5-level or above will be performed at the 3-level rate. With this information, and the assumption that all maintenance will be done as quickly as possible, but checkout of 3-level personnel will be performed whenever possible, we can now undertake the task of determining mission accomplishment with any particular skill mix.

Table 18 illustrates the expected results when varying this average performance level through the use of the TMULT functions, from 5-level to approximately 75 percent 5-level (TMULT = 1.1), to 50 percent 5-level (TMULT = 1.2), to all 3-level. Any of the other techniques for adjusting 5-level task times could also be adapted to reflect proportional levels of 5-level versus 3-level task times.

Let us now further pursue the use of the simulation models developed thus far. For example, management would like to know the expected effect of using 75% 3-level maintenance personnel with no change in number assigned. Suppose we learn from our operational audit sampling technique that the average 3-level task time increase factor is 1.5.

For illustrative purposes first assume that all tasks require two persons and no training is required. The probability that two 3-level persons are dispatched for any particular task is then approximately (.75)(.75) = .5625 assuming large population. Thus, on the average, .5625 of all tasks are performed at the 3-level task time

TABLE 16. COMPARISON OF PROGRESSIVE TMULT INCREASES

WORK CENTER →	Sorties Per Aircraft/Day	Maintenance Manhour Per Flying Hour	Average Precortie Time	Average Postsortie Time	Bomb Navigation 321C2	Automatic Flight Control 325X0	Instruments 325X1	Communications 328X0	Navigation 328X1	Electronic Warfare 328X3	Inertial Navigation 328X4	Sensors 329X0	Photographic 404X1	Electrical Systems 423X0	Environmental Systems 423X1	Egress 423X2
RESULTS OF BASELINE 5-LEVEL SIMULATION	2.28	37.66	1.87	6.17	3.13	.29	.66	.87	.46	1.55	.74	.05	.28	.63	.23	.24
RESULTS WHEN TMULT = 1.10	[illegible]	42.65	2.09	6.90	3.36	.31	.77	.93	.46	1.69	.78	.05	.35	.69	.29	.24
RESULTS WHEN TMULT = 1.20	1.97	46.12	2.28	7.58	3.87	.38	.72	1.02	.54	1.82	.96	.05	.39	.75	.27	.28
RESULTS WHEN TMULT = 1.40	1.80	50.81	2.72	8.36	4.31	.37	.95	1.17	.58	[illegible]	1.26	.07	.41	.87	.36	.36

	Fuel Systems 423X3	Pneudraulics 423X4	Aerospace Ground Equipment 423X5	Jet Engines 426X2	Flightline Maintenance 431F1	Reclamation and Repair 431R1	Special Duties 431X1	Munitions Maintenance 461X0	Gun Services 462G0	Weapons Loading 462L0	Weapons Release 462X0	Machine Shop 531X0	Metal Processing 531X2	Structural Repair 531X3	Corrosion Control 531X4	Non Destructive Inspection 531X5
RESULTS OF BASELINE 5-LEVEL SIMULATION	1.46	.98	.19	5.16	4.81	1.01	.12	4.29	1.79	3.60	2.43	.33	.05	1.94	.01	.04
RESULTS WHEN TMULT = 1.10	1.60	1.09	.21	6.45	5.36	1.13	.12	4.60	1.98	3.90	2.84	.38	.06	2.05	.01	.05
RESULTS WHEN TMULT = 1.20	1.84	1.38	.22	6.16	5.82	1.19	.10	4.90	2.35	4.24	2.98	.41	.06	2.30	.01	.04
RESULTS WHEN TMULT = 1.40	2.11	1.38	.30	6.46	6.79	1.19	.16	5.49	2.41	4.91	3.65	.47	.06	2.44	.01	.06

rate and .4375 of all tasks are performed at the 5-level speed. Therefore, we can use a TMULT factor of (.4375)(1) + (.5625)(1.5) = 1.28 to estimate the maximum accomplishment. However, if we use a different maintenance crew personnel assignment policy we might improve our accomplishment. If we assign one 5-level specialist to each crew possible in this example, then one-half of all crews will perform at the 5-level rate since crew size is 2 and one fourth of all specialists are 5-level We now assume that crews are dispatched randomly for each maintenance task, the probability that a crew of two 3-levels is dispatched for any particular task is one half. Thus on the average, half of all tasks are performed at the 3-level task time rate and half of all tasks are performed at the 5-level speed. Therefore, we can use a TMULT factor of (.5)(1) + (.5)(1.5) = 1.25 to estimate the maximum expected accomplishment. This second policy improves sortie accomplishment by approximately five percent while decreasing MMHPFH by four percent (see Table 19).

To take our example a step further, in addition to crew skill level makeup, we can choose when to dispatch maintenance crews that possess each task rate. If we were to follow the policy that crews possessing the 5-level speed. are to be dispatched whenever available we can further increase sortie rate and reduce MMHPFH during a surge effort.

TABLE 19 Comparisons of Staffing Policies

WORK CENTER	Sorties Per Aircraft/Day	Maintenance Manhour Per Flying Hour	Average Presortie Time	Average Postsortie Time	Bomb Navigation 321G2	Automatic Flight Control 325X0	Instruments 325X1	Communications 326X0	Navigation 328X1	Electronic Warfare 328X3	Inertial Navigation 328X4	Sensors 329X0	Photographic 404X1	Electrical Systems 423X0	Environmental Systems 423X1	Egress 423X2
Policy One TMULT = 1.28	1.71	48.34	2.68	9.08	4.05	.35	.85	1.23	.52	1.64	.29	.08	.39	.88	.30	.31
Policy Two TMULT = 1.22	1.78	46.27	2.44	8.68	4.02	.38	.80	.98	.55	1.84	1.02	.03	.36	.74	.26	.29
Policy Three TMULT = 1.15	1.92	42.93	2.14	7.20	3.61	.37	.75	.97	.49	1.74	.88	.05	.36	.71	.27	.26
Percent Change Policy One - Three	+12.3	-11.2	-20.1	-20.7												

WORK CENTER	Fuel Systems 423X3	Pneudraulics 423X4	Aerospace Ground Equipment 423X5	Jet Engines 426X2	Flightline Maintenance 431F1	Reclamation and Repair 431R1	Special Duties 431Y1	Munitions Maintenance 462X0	Gun Services 462G0	Weapons Loading 462L0	Weapons Release 462W0	Machine Shop 531X0	Metal Processing 531X1	Structural Repair 531X3	Corrosion Control 531X4	Non Destructive Inspection 531X5
Policy One TMULT = 1.28	1.85	1.23	.24	6.10	6.32	1.23	.12	5.20	2.52	4.47	3.14	.44	.07	2.48	.01	.07
Policy Two TMULT = 1.22	1.80	.99	.23	6.50	6.01	1.28	.14	4.81	2.11	4.28	3.05	.40	.07	2.21	.02	.05
Policy Three TMULT = 1.15	1.72	1.15	.22	6.31	5.52	1.16	.11	4.72	2.07	4.19	2.96	.39	.06	2.15	.01	.04

From the matrix output for each specialty we can now determine the probability of having an available crew possessing 5-level speed when a maintenance task must be performed. For this simplified example we have an available crew possessing 5-level speed approximately 70 percent of the time when a job arrives. Thus we can assign 70 percent of all tasks to the faster crews. This results in an average TMULT factor of .70(1) + .30(1.5) = 1.15. The results of this policy are displayed in Table 19 along with the overall percent change due to the third staffing policy being implemented rather than the first (random) policy.

As can be seen in Table 19, the use of policy three during a surge effort produces about a twelve percent improved sortie rate. However, this policy could delay 3-level upgrade and may have a negative effect for a large run (protracted war scenario).

On the other hand if we were to dispatch crews with one 5-level and one 3-level specialist whenever possible, these 3-level specialist would upgrade to the 5-level skill more quickly and would then be available to be reassigned, as 5-levels to a new crew with a lesser experienced 3-level specialist.

Each of the possible policies and scenarios can be analyzed with the models and techniques developed in this study. From all this we can now address advanced scenarios of the following type:

1. We have 210 hands-on maintenance personnel per shift, broken into specialities in a particular fashion.

2. We have 24 F-4E aircraft.

3. We have on hand inventory of some given amount. Reorder leadtime is 30 days.

4. We will assume all weather capability (or all weather will be compatible for our mission).

5. Currently 75% of all maintenance personnel are 3-level skill.

6. Check out time for 3-level personnel will not affect results.

7. Upgrade to 5-level takes six months.

8. Attrition of personnel is 10 percent per month of which half are 5-levels.

9. Replacement personnel arrive at the same rate as attrites but are all unchecked out 3-levels.

10. Management policy is to defer phase inspection during surge (first 30 days) portion of war.

11. One, and only one, 5-level (or above) is assigned to any maintenance task whenever possible.

Management would like to answer the following questions.

1. What are the expected sortie rate and MMHPFH during surge (the initial 30 days of war)?

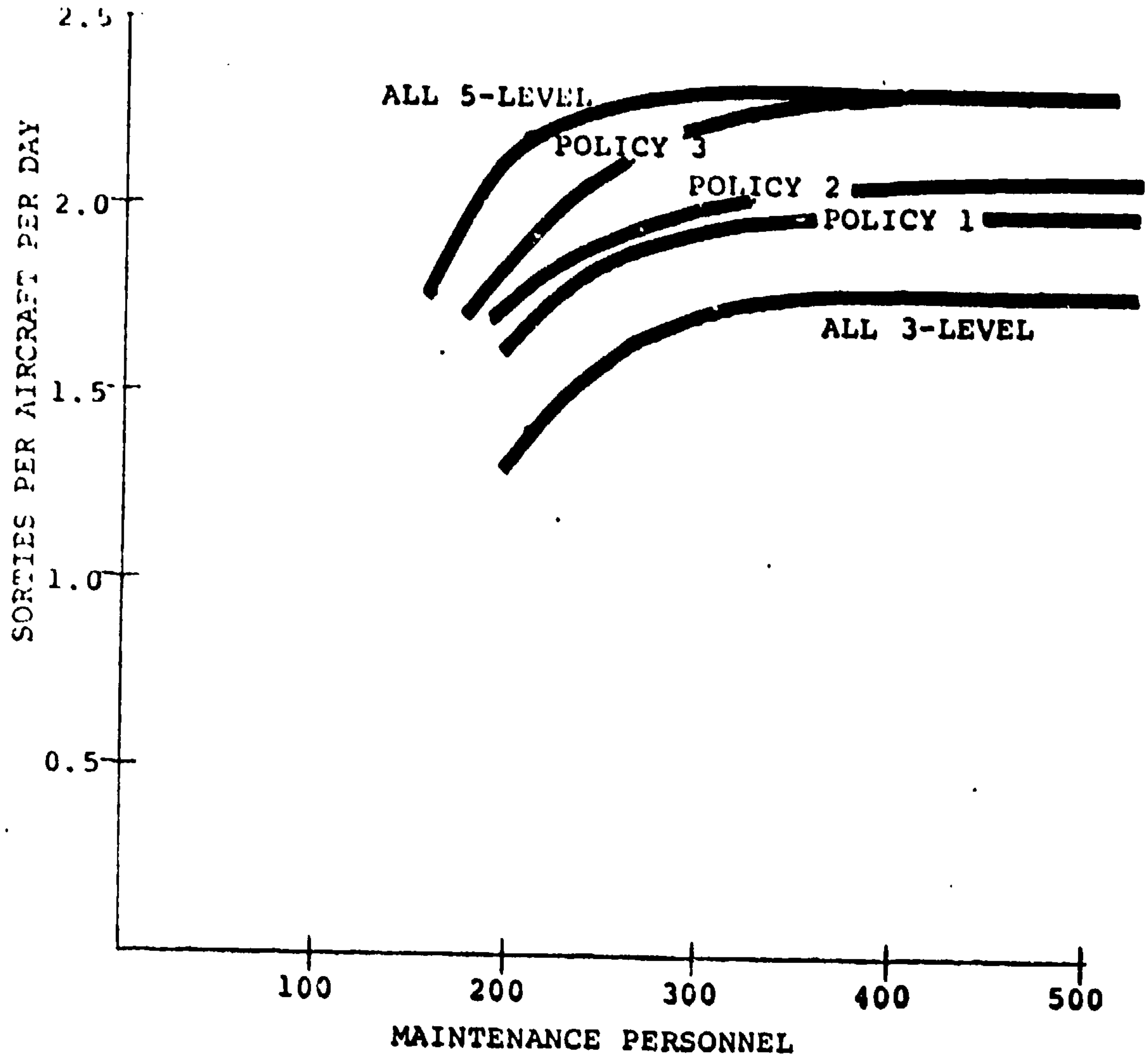
2. What are the expected tradeoffs of sortie rate and number of personnel assigned?

With this or any other particular scenario and simulation we can develop tradeoff charts to compare different management staffing policies. Figure 11 presents the tradeoff of number of maintenance personnel versus sortie rate for each of the three staffing policies we have discussed when 75 percent of the maintenance force is 3-level skill. For comparison, this figure also presents the tradeoff curves when all maintenance personnel possess 5-level or all possess 3-level.

Figure 12 presents the expected sortie rate when the average skill level of the organization is varied while holding the number of personnel constant at 210 and each of the three staffing policies is used.

If we were to generalize this method of analysis for another field we would produce the management aids represented by Figures 13 and 14. In Figure 13 we have number of personnel versus productivity. Each curve on this visual aid represents one management policy or skill situation. In Figure 14 we see the tradeoff between average skill level and productivity. Each curve would again represent a particular management personnel policy. Thus management in many areas can benefit from this type of policy comparison aid.

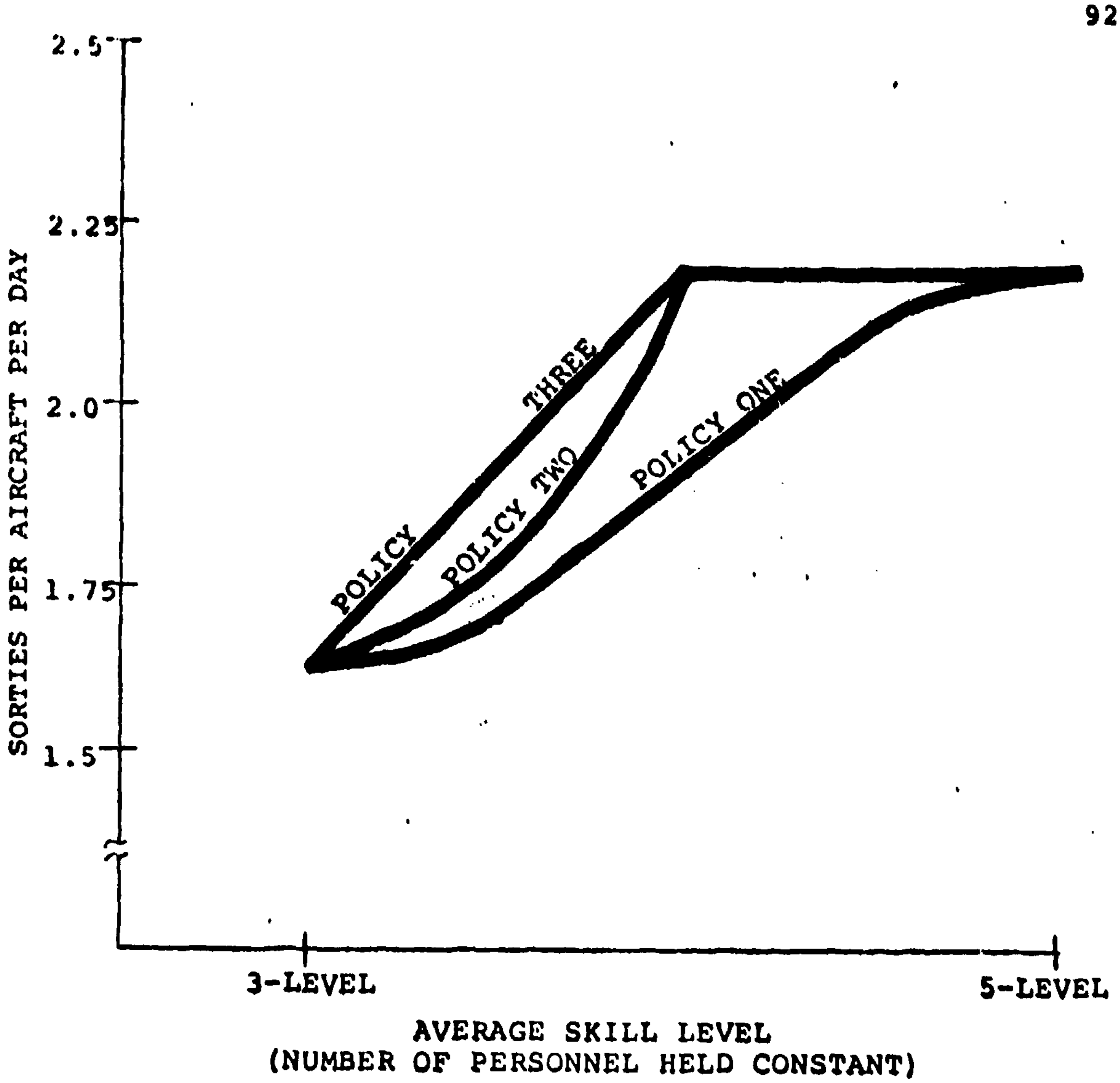
From all this we can see the expected gain in productivity when we analyze various management staffing policies and skill situations. Although the example presented here is somewhat simple in that it assumes exactly



LEGEND

Policy 1	Crew members and crews randomly assigned.
Policy 2	Crews include a 5-Level to maximum extent possible but crews are randomly assigned to tasks.
Policy 3	Crews include one 5-level whenever possible and crews including one 5-level have priority.

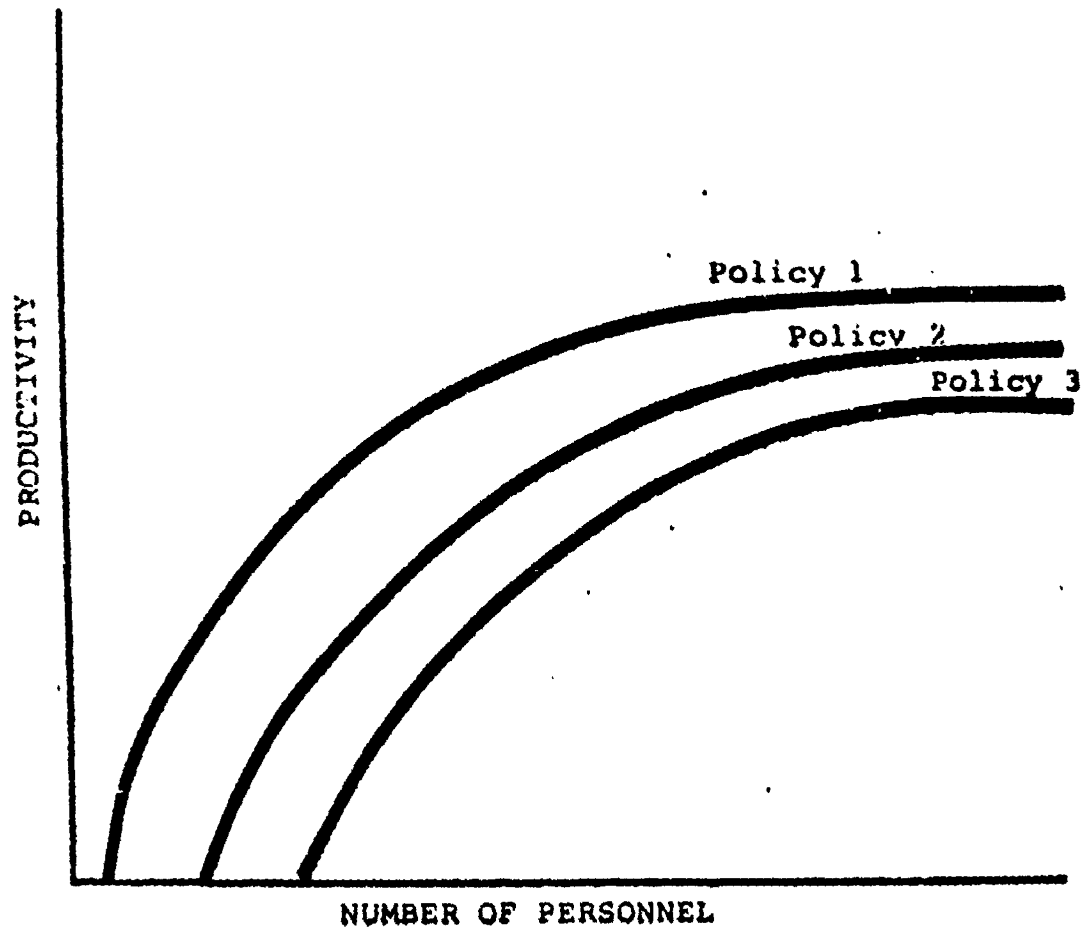
Figure 11. Assigned Personnel vs Sortie Rate



LEGEND

Policy 1	Crew members and crews randomly assigned.
Policy 2	Crews include a 5-Level to maximum extent possible but crews are randomly assigned to tasks.
Policy 3	Crews include one 5-level whenever possible and crews including one 5-level have priority.

Figure 12. Average Skill Level vs Sortie Rate



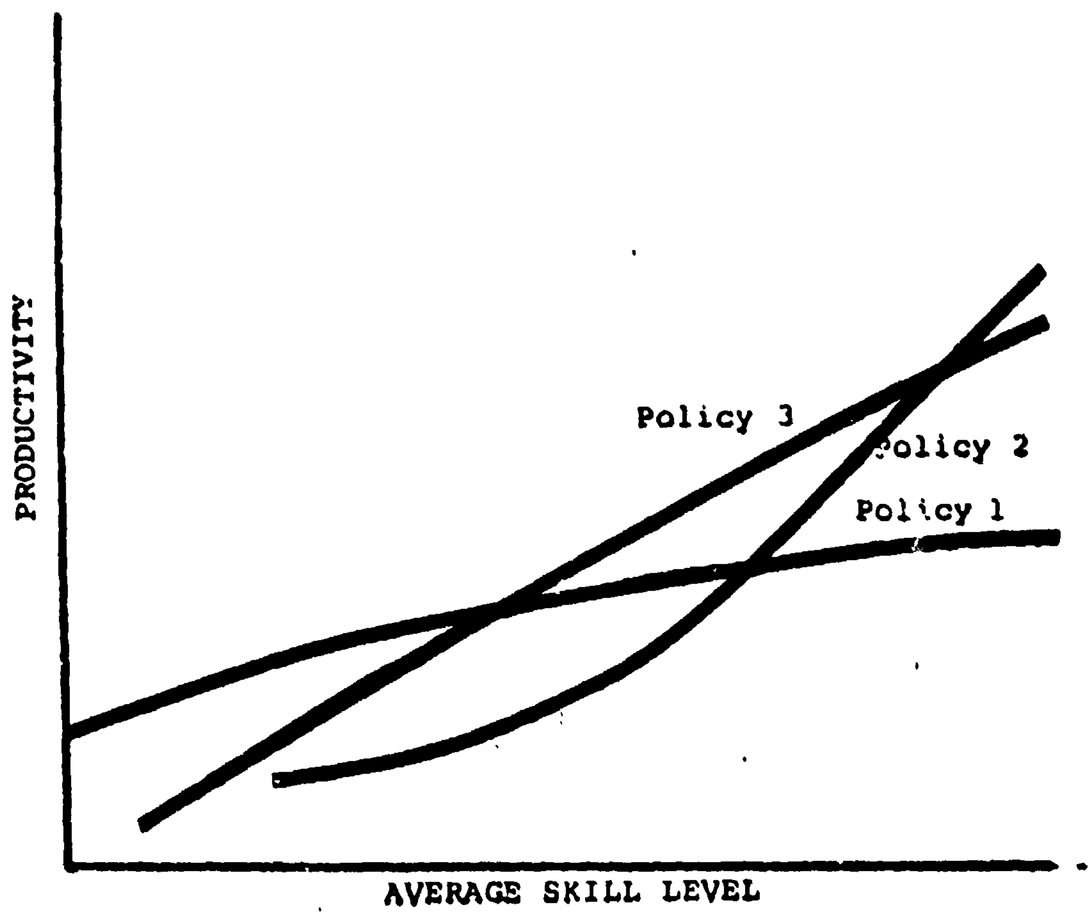
LEGEND

Policy 1 Crew members and crews randomly assigned.

Policy 2 Crews include a 5-Level to maximum extent possible but crews are randomly assigned to tasks.

Policy 3 Crews include one 5-level whenever possible and crews including one 5-level have priority.

Figure 13. Number of Personnel vs Productivity



LEGEND

Policy 1	Crew members and crews randomly assigned.
Policy 2	Crews include a 5-Level to maximum extent possible but crews are randomly assigned to tasks.
Policy 3	Crews include one 5-level whenever possible and crews including one 5-level have priority.

Figure 14. Average Skill Level vs Productivity

two person per maintenance crew, the concept and the simulation model are adaptable to many situations.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Research Problem vs Method

The research problem was to determine a method that can be used to determine the effect of a skill level change upon the sortie generation capability of a maintenance organization. The use of the operational audit technique and MDC data along with current LCOM simulation models of operational aircraft does provide such a method to analyze the expected effects. This method of skill level productivity analysis can readily be adapted to other more general problems. Job shops could be analysed in a similar fashion to determine the effects of personnel turnover or which employees to utilize for overtime work. Bank teller experience versus the number of tellers required to meet given specifications, airline maintenance and customer service systems, and air traffic control work load are but a few of the related situations that come immediately to mind as examples for which a similar analysis may be performed. Indeed, this type analysis lends itself to any nonrepetitive, large or high volume multiple task situation where experience or skill level affect individual task times.

Accuracies Achieved

The accuracy of this method is dependent upon many factors. The skill of the interviewer, the knowledge and experience of the maintenance personnel interviewed, and the precision of the LCOM networking all affect the results. The method of sampling and the number of samples can be chosen for any degree of accuracy desired.

The sample sizes required for the desired accuracy for any parameter of interest can quickly be calculated using the techniques explained in the experimental design.

Further Study

This study was limited to the F-4E aircraft and the numbers/factors calculated can only be applied to this aircraft. However, the technique is general and can apply to any aircraft system. It is also recommended that a similar analysis be performed for several other aircraft weapon systems and the results be compared to determine similarities and/or common factors. It is further recommended that a stratified sampling technique be utilized in such a follow-on study in order to verify the categorizing of work centers and resulting multiplication factors. The following method is proposed for a follow-on study:

1. Decide upon the weapon system to be modeled.

2. Decide the accuracy desired in terms of Type I and Type II error.

3. For aircraft with existing LCOM models, divide work centers to be studied into "small difference" and "large difference" categories according to the Air Force Specialty Codes as in Table 17.

4. Draw task times samples until the number of samples equals or exceeds the "n" from the formula

$$\hat{n} = [\frac{d\ S}{a\ X}]$$

as defined on page 41.

5. Test the power of the test as described on page 42.

6. Increase "n" as necessary to meet both restrictions.

7. For aircraft weapon systems without current LCOM models perform the complete operational audit to include both 5-level and 3-level task times.

8. Network the simulation model as necessary.

9. In either case run the model with 5-level data and with 3-level data (either individual task times or grouped and weighted factor multiplication) utilizing the source operations scenario.

10. Run sufficient simulation time to achieve the accuracy desired (the same method as above will determine the run time necessary).

11. Analyze the results and report findings.

Use of LCOM

The development of LCOM required more than one hundred man years of effort and several civilian companies as well as Air Force resources. The flexibility and detail available in this programming framework make it ideal for the type of study represented by this research.

LCOM certainly is a feasible tool which, with all due caution, can be used for many varied study efforts and research problems. The use of the operational audit technique and MDC data also deserve serious consideration for future use.

Adaptation to Other Current Studies

During the course of this study the research became aware of several other on-going studies that might benefit from the techniques developed in this study. For example, a research firm is studying the effect upon aircraft turn time (servicing time) and sortie generation capabilities when maintenance personnel must wear chemical defense equipment. If one were to consider normal maintenance (the 5-level baseline model utilized in this study) and degraded (handicapped by wearing chemical defense equipment) maintenance capabilities, the task times determined through direct measurement during practice situations or thorugh an operational audit technique, the same simulation technique could be utilized to answer nearly all "what if" questions. It is recommended that the technique developed in this study be adapted to on-going studies such as the above.

Research Accomplishments

As stated earlier, about 60 percent of the total defense budget of the United States goes to pay for defense personnel. Of the defense manning about 35 percent relate to aircraft maintenance personnel. This study develops an approach to assess the effect of skill level and number of personnel upon expected mission accomplishment. The use of the techniques developed in this study can result in savings in terms of manpower and management personnel policies. The sampling technique described in this study can save money and time. By using this sampling technique the required computer time is reduced to approximately one quarter of that previously required for similar studies and three to six man months of data collection and analysis time are saved.

LIST OF REFERENCES

1. Comptroller General of the United States. Determining Requirements for Aircraft Maintenance Personnel Could Be Improved - Peacetime and Wartime, report to the Senate Committee on Appropriations, May 1977.

2. White, John P., Dr., Assistant Secretary of Defense Manpower Reserve Affairs and Logistics. Memorandum on Manpower Analysis Requirement for Systems Acquisition, August 17, 1978.

3. Ibid, No. 1

4. Ibid, No. 2

5. Air Force Regulation 50-23, On-The-Job Training, May 29, 1979.

6. Ibid, No 1

7. Eckstrand, Gordon A. Manpower and Logistics Factors in Weapon System Development, unpublished report of Air Force Human Resources Laboratory, August 1979.

8. Moore, S. Craig. Letter from Rand Corporation to Air Force Maintenance and Supply Management Engineering Team, Wright-Patterson Air Force Base, Ohio, January 8, 1979.

9. French, Bruce D., Captain, United States Air Force, and Steele, Robert P., Captain, United States Air Force. Productivity: A Function of Skill, LSSR 11-79B, February 1979.

10. Asiala, Carl F., Loy, Susan L., Hameister, Ralph O. and Maher, Frank A. Development of Models of Maintenance Resources Interaction: Definition of Data Requirements, McDonnell Douglas Astronautics Company, St Louis, Missouri and Advanced Systems Division, Wright-Patterson Air Force Base, Ohio, May 1978.

11. Keller, Kenneth R., Major, United States Air Force. Logistics Composite Model Student Training Text, 4400 MES/LC, Langley Air Force Base, Virginia, July 1977.

12. Technical Order 1F-4E-06, Technical Manual Aircraft Maintenance Work Unit Code Manual USAF Series F-4E Aircraft, June 1, 1978.

13. Air Force Manual 66-1, Maintenance Management, August 15, 1979.

14. Simulating Maintenance Manning for New Weapon Systems: Building and Operating a Simulation Model. Report No. AFHRL-TR-74-97(II), Advanced Systems Division, Wright-Patterson Air Force Base, Ohio, December 1974.

15. Gunkel, Richard. Work Center Task Time Evaluation, letter from Tactical Air Command, Seymour Johnson Air Force Base, North Carolina, September 1974.

16. Ibid, No. 16

17. Giffin, Walter C. Introduction to Operations Engineering, Richard D. Irwin, Inc., 1971.

18. Lindman, Harold R. Analysis of Variance in Complex Experimental Designs, W. H. Freeman & Company, 1974.

19. Ibid, No. 18

20. Hogg, Robert V. and Craig, Allen T. Introduction to Mathematical Statistics, Third Edition, Macmillan Publishing Co., Inc., New York, 1970.

BIBLIOGRAPHY

Asiala, Carl F., Loy, Susan L., Hameister, Ralph O., and Maher, Frank A. Development of Models of Maintenance Resources Interaction: Definition of Data Requirements, McDonnell Douglas Astronautics Company, St Louis, Missouri and Advanced Systems Division, Wright-Patterson Air Force Base, Ohio, May 1978.

Askren, William B., Campbell, Wendy B., Seifert, Deborah J., Hall, Thomas J., Johnson, Robert C., Sulzen, Robert H. Feasibility of a Computer Simulation Method for Evaluating Human Effects on Nuclear Systems Safety, AFHRL-TR-76-18, AFWL-TR-76-15, Advanced Systems Division, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, May 1976.

Askren, William B., Regulinski, Thaddeus L., Quantifying Human Performance Reliability, AFHRL-TR-71-22, Advanced Systems Division and Air Force Institute of Technology, Air Force Human Resources Laboratory, Air Force Systems Command, Brooks Air Force Base, Texas, June 1971.

Automated Performance Monitoring and Assessment for DCS Digital Systems, RADC-TR-77-327, GTE Sylvania, Inc., Needham Heights, Massechusetts, October 1977.

Balut, Stephen J. and Stoloff, Peter. An Inventory Planning Model for Navy Enlisted Personnel, 55 000181.00, Center for Naval Analyses, Arlington, Virginia, May 1977.

Brown, George H., Angell, David, and Anneser, Robert E. Research Memorandum, A Survey of Activities of Aircraft Maintenance Personnel, George Washington University, Washington D.C., October 1962.

Carpenter-Huffman, Polly and Rostker, Bernard. The Relevance of Training for the Maintenance of Advanced Avionics, R-1894-AF, Rand Corporation, Santa Monica, California, December 1976.

Comptroller General of the United States. Determining Requirements for Aircraft Maintenance Personnel Could Be Improved - Peacetime and Wartime, report to the Senate Committee on Appropriations, May 1977.

Drake, Kenneth L., Sanders, Mark S., Crooks, William H. and Weltman, Gershon. Comparative Studies of Organizational Factors in Military Maintenance, PTR-1043-77-10, Perceptronics, Woodland Hills, California, October 1977.

Drake, Kenneth L., Sanders, Mark S., Crooks, William H. and Weltman, Gershon. Comparative Studies of Organizational Factors in Military Maintenance, PTR-1043-77-7, Perceptronics, Woodland Hills, California, October 1977.

Dryden, J. H. Acquisition Management, Development of Human Factors Engineering for System/Equipment Programs, ASD Pamphlet 800-2, Department of the Air Force, Headquarters Aeronautical Systems Division (AFSC), Wright-Patterson Air Force Base, Ohio, June 29, 1979.

Eckstrand, Gordon A. Manpower and Logistics Factors in Weapon System Development, unpublished report of Air Force Human Resources Laboratory, August 1979.

Edwards, John O., Captain, United States Air Force. Comparative Analyses of Enlisted Job Satisfaction as Measured by the Occupational Attitude Inventory, AFHRL-TR-78-61, Occupation and Manpower Research Division, Air Force Human Resources Laboratory, Brooks Air Force Base, Texas, October 1978.

Engineering Experiment Station. North American Aviation Production Scheduling Research Project, Final Report, Appendix, Project E.E.S. 124, The Ohio State University, Columbus, Ohio, July 31, 1957.

Fisher, Cynthia D. and Pritchard, Robert D. Effects of Personal Control, Extrinsic Rewards, and Competence on Intrinsic Motivation, AFHRL-TR-78-20, Purdue Research Foundation, West Lafayette, Indiana and Air Force Human Resources Laboratory, Air Force Systems Command, Brooks Air Force Base, Texas, July 1978.

Fitzgerald, Baldwin G., Captain, United States Air Force and Miller, Phillip E., Captain, United States Air Force. A System Dynamics Study of the Factors Used in the Measurement of an Aircraft Wing's Capability, LSSR 23-78A, Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio, June 1978.

Foley, John P., Jr. Hard Data Sources Concerning More Cost Effective Maintenance, AFHRL-TR-76-58, Advanced Systems Division, Air Force Human Resources Laboratory, Air Force Systems Command, Brooks Air Force Base, Texas, July 1976.

French, Bruce D., Captain, United States Air Force and Steele, Robert P., Captain, United States Air Force. Productivity: A Function of Skill, LSSR 11-79B, February 1979.

Gay, Robert M. Estimating the Cost of On-The-Job Training in Military Occupations: A Methodology and Pilot Study, AD-783-936, Rand Corporation, April 1974.

Giffin, Walter C. Introduction to Operations Engineering, Richard D. Irwin, Inc., 1971.

Goclowski, John C., King, Gerard F., and Ronco, Paul G. Integration and Application of Human Resource Technologies in Weapon System Design: Coordination of Five Human Resource Technologies, AFHRL-TR-78-6(I), Dynamics Research Corporation, Wilmington, Massechusetts, March 1978.

Goclowski, John C., King, Gerard F., and Ronco, Paul G. Integration and Application of Human Resource Technologies in Weapon System Design: Coordination of Five Human Resource Technologies, AFHRL-TR-78-6(II), Dynamics Research Corporation, Wilmington, Massechusetts March 1978.

Gould, R. Bruce. Review of an Air Force Job Satisfaction Research Project: Status Report Through September 1970, AFHRL-TR-76-75, Occupation and Manpower Research Division, Lackland Air Force Base, Texas, Air Force Human Resources Laboratory, Brooks Air Force Base, Texas, December 1976.

Gould, R. Bruce. Air Force Occupational Attitude Inventory Development, AFHRL-TR-78-60, Occupation and Manpower Research Division, Air Force Human Resources Laboratory, Brooks Air Force Base, Texas, October 1978.

Gunkel, Richard. Work Center Task Time Evaluation, Tactical Air Command letter, Seymour Johnson Air Force Base, North Carolina, September 1974.

Hendrix, William H., Major, United States Air Force. Contingency Approaches to Leadership: A Review and Synthesis, AFHRL-TR-76-17, Air Force Human Resources Laboratory, Air Force System Command, Brooks Air Force Base, Texas, June 1976.

Hernandez, Florencio, Lt Colonel, United States Air Force, Coco, Terrell T., Captain, United States Air Force, and Hamm, John L., Captain, United States Air Force. A Study of the Impact of Personality Differences on Troubleshooting Performance, LSSR 33-77A, Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio, June 1977.

Hogg, Robert V. and Craig, Allen T. Introduction to Mathematical Statistics, Third Edition, Macmillan Publishing Co., Inc., New York, 1970.

Horowitz, Stanley. Maintenance Personnel Effectiveness in the Navy, AD-A021-581, Center for Naval Analyses, Arlington, Virginia, January 1976.

Hypothetical Pre-Accomplishment Time Data for 16 Unscheduled AGE Maintenance Tasks, Rand Corporation, Santa Monica, California.

Kelly, Carl S., Lt Colonel, United States Air Force. An Improved Approach to Managing the Classification, Training, and Assignment of Aircraft and Avionics Maintenance Personnel, Report No. 5968, Air War College Air University, Maxwell Air Force Base, Alabama, April 1976.

Keller, Kenneth R., Major, United States Air Force. Logistics Composite Model Student Training Text. 4400 MES/LC, Langley Air Force Base, Virginia, July 1977.

King, William J., and Duva, James S. ATE: Bane or Blessing for the Technician, NAVTRAEQUIPC-IH-301, Naval Training Equipment Center, Orlando, Florida, March 1978.

Kuhn, Coleman Daniel, Jr. Thesis: Analysis of Organizational Aviation Maintenance Training Within the United States Marine Corps, Naval Postgraduate School, Monterey, California, December 1977.

Leabo, Dick A. Basic Statistics, Richard D. Irwin, Inc., 1972.

Lindman, Harold R. Analysis of Variance in Complex Experimental Designs, W. H. Freeman and Company, 1974.

Lintz, Larry M. Relationships Between Design Characteristics of Avionics Subsystems and Training Cost, Training Difficulty, and Job Performance, AFHRL-TR-72-70, Air Force Human Resources Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, January 1973.

Moore, S. Craig, Rand Corporation letter to Air Force Maintenance and Supply Management Engineering Team, Wright-Patterson Air Force Base, Ohio, January 8, 1979.

Nanda, Ravinder and Adler, George L. Learning Curves Theory and Application, AIIE-WM&ME-77-6, Publication No. 6, Work Measurements and Methods Engineering Division, American Institute of Industrial Engineers, Inc., Norcross, Georgia, 1977.

Occupational Survey Branch, Aircraft Maintenance Career Ladder, AFPT-90-431-210, United States Air Force Occupational Measurement Center, Lackland Air Force Base, Texas, June 15, 1977.

Occupational Survey Branch, Occupational Survey Report, Helicopter Maintenance Career Ladder, AFPT 90-431-288, United States Air Force Occupational Measurement Center, Lackland Air Force Base, Texas, November 30, 1977.

Pincus, John and Pascal, Anthony H. Education and Human Resources Research at Rand, P-5748, Rand Corporation, Santa Monica, California, January 1977.

Potter, Norman R. and Thomas, Donald L. Evaluation of Three Types of Technical Data for Troubleshooting: Results and Project Summary, AFHRL-TR-76-64(I), Systems Research Laboratories, Inc., Dayton, Ohio and Advanced Systems Division, Wright-Patterson Air Force Base, Ohio, Air Force Human Resources Laboratory, Brooks Air Force Base, Texas, September 1976.

Powers, Thomas E., PhD. Selecting Presentation Modes According to Personnel Characteristics and the Nature of Job Tasks, Part I: Job Tasks, University of Maryland Baltimore County, Baltimore, Maryland, January 1977.

Pritchard, Robert D and Montagno, Ray V. Effects of Specific vs Nonspecific and Absolute vs Comparative Feedback on Performance and Satisfaction, AFHRL-TR-78-12, Purdue Research Foundation, West Lafayette, Indiana, Air Force Human Resources Laboratory, Air Force Systems Command, Brooks Air Force Base, Texas, May 1978.

Prichard, Robert D., Montagno, Raymond V. and Moore, John R. Enhancing Productivity Through Feedback and Job Design, AFHRL-TR-78-44, Purdue Research Foundation, West Lafayette, Indiana, Air Force Human Resources Laboratory, Brooks Air Force Base, Texas, August 1978.

Prophet, Wallace W. The U.S. Army in the 1970s: Developments in Training and Manpower Technologies, PP 77-01, Seville Research Corporation, Pensacola, Florida, February 1977.

Sauer, Daniel W., Campbell, Wendy B., Potter, Norman R. and Askren, William B. Human Resource Factors and Performance Relationships in Nuclear Missile Handling Tasks, AFHRL-TR-76-85, AFWL-TR-76-301, Systems Research Laboratories, Inc., Dayton, Ohio; Advanced Systems Division, Wright-Patterson Air Force Base, Ohio; Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico, Air Force Human Resources Laboratory, Air Force Systems Command, Brooks Air Force Base, Texas, May 1977.

Sticht, Thomas G., Fox, Lynn C., Hauke, Robert N. and Zapf, Diana W. Integrated Job Skills and Reading Skills Training System, NPRDC TR 77-41, Human Resources Research Organization, Alexandria, Virginia, September 1977.

Technical Order, Preventive Maintenance Program General Requirements and Procedures, T.O. 00-20-1, May 1, 1978.

USS ARD-7 Manning Study Report, Naval Ship Engineering Center, Hyattsville, Maryland, 6112F-2150, September 1, 1976.

Voth, John C. E. Human Resource Accounting, Technical Report No. 102, Wichita State University.

Watson, Thomas W., Zumbro, Patrick A., Sergeant, United States Air Force. Job Enrichment: Evaluation with Implications for Air Force Job Redesign, AFHRL-TR-77-56, Occupation and Manpower Research Division, Brooks Air Force Base, Texas, Air Force Human Resources Laboratory, Brooks Air Force Base, Texas, October 1977.

White, John P., Dr., Assistant Secretary of Defense Manpower Reserve Affairs and Logistics. Memorandum on Manpower Analysis Requirement for Systems Acquisition, August 17, 1978.

Whiton, Justin C. and Lindsay, William A. Enlisted Personnel Assignment System Research: Status Report, IR Study 10364, OAD-CR-87, General Research Corporation, McLean, Virginia, December 1974.

Winkler, Robert L and Hays, William L. Statistics: Probability, Inference, and Decision, Holt, Rinehart and Winston, 1975.

APPENDIX A

Selected Reference Material

Chapter 9

MAINTENANCE EXPERIENCE DATA (AFM 66-1)

9-1. PURPOSE. The purpose of this chapter is to outline the Maintenance Data Collection (MDC) system established by AFR 66-14 and AFM 66-1. The MDC is the primary source for Air Force reliability and maintainability data; therefore, basic understanding of its objectives, uses, and limitations is essential to R & M data users.

9-2. OBJECTIVES. The Maintenance Data Collection system was designed primarily as a base level production credit and management information system. The objectives are to provide maintenance managers with information about the production accomplished by the assigned maintenance personnel; and to identify the equipment on which work was accomplished, why the work was required, and the action required to complete the job. The MDC system identifies maintenance requirements and problem areas so that appropriate management action can be taken to effectively support and meet the established operational requirements. In addition, the MDC system is designed to provide data to AFLC for maintenance engineering and logistics management. Selected data is also provided to the major commands and HQ USAF in accordance with AFMs 66-267 and 66-271.

9-3. SCOPE. The MDC system is applicable to all functions outlined in AFM 66-1, and requires that all maintenance actions involving direct labor expenditures be recorded and reported in this system unless exempted by TO 00-20-2. The system is applicable to the life cycle of aircraft, missiles, ground communications, electronics, and meteorological equipment, and related end items beginning with operational test and evaluation as described in AFR 80-14. This includes compatible data reporting on contractor maintained equipment and maintenance accomplished in depot facilities.

9-4. DOCUMENTATION CONCEPT. The AFTO Forms 346, 349, and 350 are used as source documents for the maintenance data collection system.

a. Recording Concept procedures are divided into two basic categories identified as on-equipment and off-equipment maintenance documentation.

(1) Maintenance actions accomplished on complete end items of equipment (aircraft, missiles, removed engines, ground communications electronics-meteorological (CEM), trainers, Aerospace Ground Equipment (AGE) and nuclear weapons) are identified as on-equipment work. This primarily consists of support general tasks, inspections, removal and replacement of components, fix-in-place maintenance actions, and modifications.

(2) In-shop maintenance actions involving intermediate level maintenance on removed components is identified as off-equipment maintenance. This primarily consists of bench check, repair or modification of components and assemblies, and nondestructive inspection.

(3) If maintenance is done on components that are removed or removed and replaced to facilitate maintenance in the same room or one immediately adjacent to the end item; this is recorded as on-equipment maintenance. If the individual that removed the component has to leave the immediate area (defined as out-of-sight), an AFTO Form 350 will be prepared to identify the status of the removed component. In this regard, when personnel from one workcenter remove an item and send it to personnel with a different workcenter code for maintenance, the latter workcenter will record it as off-equipment maintenance.

(4) Due to management requirements, unique procedures exist for engines. All maintenance accomplished on gas turbine and reciprocating engines installed in aircraft, missiles, or AGE will be recorded as on-equipment maintenance. Removal and replacement of gas turbine and reciprocating engines for aircraft, missiles, or AGE will be recorded as on-equipment maintenance with the engine treated as a component. Shop work on all removed gas turbine engines and aircraft reciprocating engines will be treated as end item maintenance with on-equipment and off-equipment recording concepts applying. (TO 00-20-2-4). Shop work on reciprocating engines removed from AGE will be treated as component maintenance and the off-equipment maintenance concept will apply.

(5) Each workcenter participating in a job will record maintenance actions and labor expenditures. The documentation responsibility rests with the senior representative from the workcenter. These documents will be returned to the workcenter supervisor who will check for accuracy and completeness prior to submission for processing.

b. Data Forms:

(1) Use of the AFTO Form 349. The AFTO Form 349, "Maintenance Data Collection Record," was designed with sufficient flexibility for use by the majority of organizations in recording maintenance actions on various types of equipment. Recording and data collection procedures pertaining to this form are outlined in the 00-20-2-series technical orders.

(a) For on-equipment work the primary entries required on the AFTO Form 349 are block 1 (Job Control Number), block 2 (Workcenter), block 3 (ID Number), block 6 (Time, as applicable), and columns B through K. For in-shop engine work, primary entries are required in blocks 1 and 2, block 4 (Engine ID) and in columns B through K. For off-equipment work on removed components, primary entries are required in blocks 1, 2, and block 3 or 5; block 19 (Federal Supply Class (FSC)), block 20 (Part Number), and columns B through K.

(b) Up to five related on-equipment maintenance actions covered by a single job control number against a single ID number, and accomplished by a single workcenter may be reported on a single copy

Copy available to DTIC does not permit fully legible reproduction

of the AFTO Form 349. If more action lines are required, another AFTO Form 349 containing the same job control number, ID number and workcenter code is completed and the actions continued. This recording procedure also applies to off-equipment actions; however, on-equipment and off-equipment actions will not be combined on a single copy of the AFTO Form 349. The four items could be reported by a single line entry if the job control number, work unit, action taken, how malfunctioned and when discovered codes are all the same and a unit count of four is entered. Similarly the AFTO Forms 350 prepared for shop processing of the four black boxes may reflect a quantity of more than one only if the job control number, work unit code, federal supply class and part number are the same. If these elements are different, a separate AFTO Form 350 must be prepared for each item. Serially controlled and time change items (with an asterisk in the work unit code manual) must be recorded on an individual basis. (for example, only one item per AFTO Forms 349 and 350).

(c) The AFTO Form 349 can be used for identification of both the end item of equipment and a component for engine change actions, for weapon systems and equipment that are managed under the Advanced Configuration Management System (ACMS), for time change items, for special reporting on tires, and for reporting off-equipment maintenance actions

(2) Use of the AFTO Form 350. The AFTO Form 350, "Reparable Item Processing Tag," is a two-part perforated form that is attached to components that are removed from equipment end items and serves as an identification and status tag. Another important aspect of this form is that it serves as a source document pertaining to Repaired This Station (RTS), Not Repaired This Station (NRTS), and condemnation actions for the supply system. This information is input to the base supply computer to identify stockage requirements. Information pertaining to RTS, NRTS, and condemnations is also forwarded through the supply system to AFLC as factors for computing the world-wide spares requirements. Recording procedures for the AFTO Form 350 are outlined in the 00-20-2-series technical orders.

(3) Use of the AFTO Form 346, "Maintenance Data Collection Production and Scheduling Record." The AFTO Form 346 is used for scheduling the calibration of Precision Measuring Equipment (PME) and for recording all maintenance on precision measurement equipment for input to the MDC system. The AFTO Form 346 may also be used for scheduling calendar maintenance requirements on any equipment within the maintenance complex. Note that this pertains only to calendar requirements. Scheduling procedures pertaining to the AFTO Form 346 are outlined in AFR 66-267. Maintenance recording procedures for the AFTO Form 346 on PME are outlined in TO 00-20-10-6

c. Data Elements:

(1) Job Control Number (JCN). The JCN consists of seven characters, the first three are the Julian date and the last four are a unique job number for that date. This provides a means to tie together all on- and off-equipment actions taken, man-hours expended, and parts consumed to satisfy a maintenance requirement whether it be a discrepancy, an inspection, or a TCTO. Every action taken that is related to a job, regardless of workcenter, time or place, will carry the same job control number that was originally assigned to the job. This procedure is necessary to permit control of all related actions, and to provide the capability to tie them together in data systems to identify the total job for analysis purposes.

(2) Workcenter Code. The workcenter code consists of five characters that identify organizational elements to which maintenance personnel are assigned, or locations to which they may be dispatched. Standard workcenter codes are used by all organizations engaged in the maintenance functions outlined in AFM 66-1. In general, the code entered in the workcenter block of the AFTO Form 349 indicates the workcenter of the individual doing the work and not necessarily where the work is accomplished.

(3) Identification (ID) Number. The ID number consists of six characters, and is used to identify equipment on which work was performed or from which an item was removed. The first character of the ID number is the first character of the owning workcenter code. The second character of the ID number is the first character (prefix) of the equipment classification code such as A for aircraft, B for Ground Radar or M for Ground Launched Missiles (AFM 300-4, ADE MA-156-XI). The last four characters of the ID number normally are the last four positions of the equipment serial number. Detailed procedures for assigning ID numbers are contained in AFM 66-267.

(4) Equipment Classification Code. The equipment classification code consists of three characters, and is assigned to identify aircraft, missiles, ground communications, electronics, and meteorological equipment, AGE, trainers, engines, ground launched missile real property installed equipment, munitions, and precision measurement equipment. Codes are also assigned for research and development and shop work. Most of the equipment classification codes are assigned to specific equipment such as LGM-30B missiles. Some of the codes are assigned by category of equipment or work such as nonregistered AGE and shop work that is not identified to a weapon or support system. The authorized equipment classification codes are contained in TO 00-20-2.

(5) Type Maintenance Code. The type maintenance code consists of one character and is used to identify the type of work that was accomplished such as scheduled or unscheduled maintenance. Type maintenance codes are listed in each work unit code manual for individual types of equipment. A complete list of authorized type maintenance codes is contained in AFM 300-4, volume XI.

(6) Work Unit Code. The work unit code consists of five characters, and is used to identify the system, subsystem, and component on which maintenance is required or on which maintenance was accomplished. These codes are published in work unit code manuals for each weapon and support system and in code manuals by type of equipment for selected ground CEM, trainers, AGE, munitions, PME,

and shop work. A limited number of work unit codes are assigned in a special category to identify tasks of a general nature such as equipment servicing, cleaning, inspection, storage ground safety, record keeping, weapons handling, and repetitive shop tasks. Although they are work unit codes, they are identified as "Support General Codes." The first two positions of the work unit codes for aircraft, ground radar, and missiles are standard system codes. They identify functional systems such as flight control system, codes antenna system, or launch control system. The first two positions of the work unit codes for support equipment identify types of equipment, such as ground powered generators, or end items of equipment, such as a trainer. The first position of support general codes begin with a zero; and this is standard in all work unit code manuals. The third and fourth positions of the work unit code identify subsystem or major assembly. The fifth position of the work unit code normally identifies repairable items.

(7) Units Completed. The work unit code in combination with an action taken code is used to describe a "unit of work." An entry of one or more units completed must also be made in the UNITS block of the data collection form in order to show a completed action. An example of a unit of work would be a work unit code for an antenna, with an action taken code for removed and replaced, and a unit count of one, for example, one antenna removed and replaced. By using additional codes to identify the end item, the type of maintenance being accomplished, when the maintenance requirement was discovered, how the item malfunctioned, and the time expended in accomplishing the work, and the production credit system also provides information essential for maintenance and materiel management.

(8) Action Taken Code. The action taken code consists of one character used to identify the maintenance action that was taken, such as remove and replace. Action taken codes are standard for all equipment and are listed in all work unit code manuals. A complete list of authorized action taken codes is contained in AFM 300-4, volume XI.

(9) When Discovered Code. The when discovered code consists of one character and is used to identify when a defect or maintenance requirement was discovered, such as during a quality control inspection. When discovered codes are listed in each work unit code manual for individual types of equipment. A complete list of authorized when discovered codes is contained in AFM 300-4, volume XI. Only that portion of the when discovered code definition that applies to equipment listed in the work unit code manual is to be used. For example, when discovered code D, In-Flight-No Abort/During AGE Operation, would be listed in the AGE work unit code manual as D, During AGE Operation.

(10) How Malfunctioned Code. The how malfunctioned code consists of three characters and is used to identify how the equipment malfunctioned, such as cracked. To provide maximum utility, these codes are also used to identify time compliance technical order status requirements, or to show that a maintenance action did not result from a defect. A complete list of authorized how malfunctioned codes is contained in AFM 300-4, volume XI, in both alphabetical (definition) and numerical (code) sequence. Only those how malfunctioned codes that are applicable will be listed in each work unit code manual. For example, how malfunctioned codes applicable only to a solid rocket missile will not be listed in a ground CEM work unit code manual.

Note: Due to the nature of support type work, the recording of action taken, when discovered, and how malfunctioned codes is not required with support general work unit codes.

9-5. The foregoing paragraphs of this chapter describe the MDCS objectives and reporting concept as related to the base maintenance environment. In order to provide AFLC data on maintenance events as they occur worldwide, most of the data documented at AF bases under the TO 00-20-2 series are submitted to HQ AFLC for use in logistic support and related engineering decisions. These data are received and processed centrally at HQ AFLC in the DO56 Product Performance System. This data system not only receives and output reports containing Reliability and Maintainability (R and M) factors within its established computer programs but also services other interfacing data systems with source data. Some of the interfacing data systems also output reports containing R and M factors individually unique to their established computer program controls. Figures 9-1 through 9-18 illustrate the data flow from point of origin through the DO56 major system processes and to other interfacing systems which are driven by the same source data. The following pages of this chapter explain some of the terms used in the DO56 and samples of output reports containing R and M factors; however, for a full understanding of system capabilities refer to AFLCM 66-15 and 171-45.

9-6. Definitions of R and M parameters and terms used in the DO56 data system:

a. Type How Malfunctioned Codes.

(1) Type 1—These codes indicate that the item no longer can meet the minimum specified performance requirement due to its own internal failure pattern.

(2) Type 2—These codes indicate that the item can no longer meet the specified performance requirement due to some induced condition and not due to its own internal failure pattern.

(3) Type 6—These codes indicate maintenance resources were expended due to policy, modifications, items location, cannibalization and other no defect conditions existing at the time maintenance was accomplished.

b. Failure occurrences. The computer definition of a failure occurrence related to a Work Unit Code is: "any Type 1 How Malfunctioned code reported in combination with an action taken indicating repair, adjustment or item replacement and one or more units produced.

c. Quantity per Application (QPA). This is the quantity of identical installed items on a single unit of equipment that are reportable under the same work unit code.

Copy available to DTIC does not permit fully legible reproduction

MAINTENANCE DATA COLLECTION SYSTEM

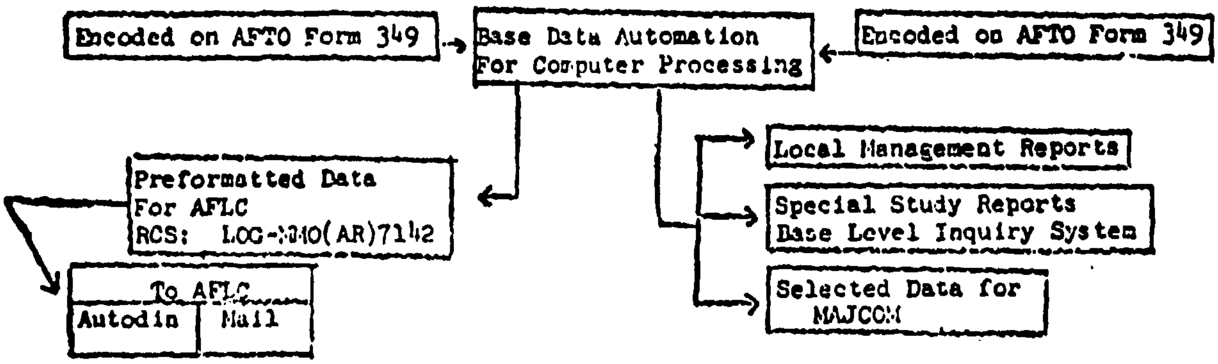
REPORTING AT AF BASES

"ON" EQUIPMENT

Corrective and Preventive Maintenance at or on the Aircraft or Equipment

"OFF" EQUIPMENT

Corrective and Preventive Maintenance Accomplished in Repair Shops on Items Removed From Aircraft or Equipment



AFLC DO56 WEEKLY COMPUTER PROCESSES

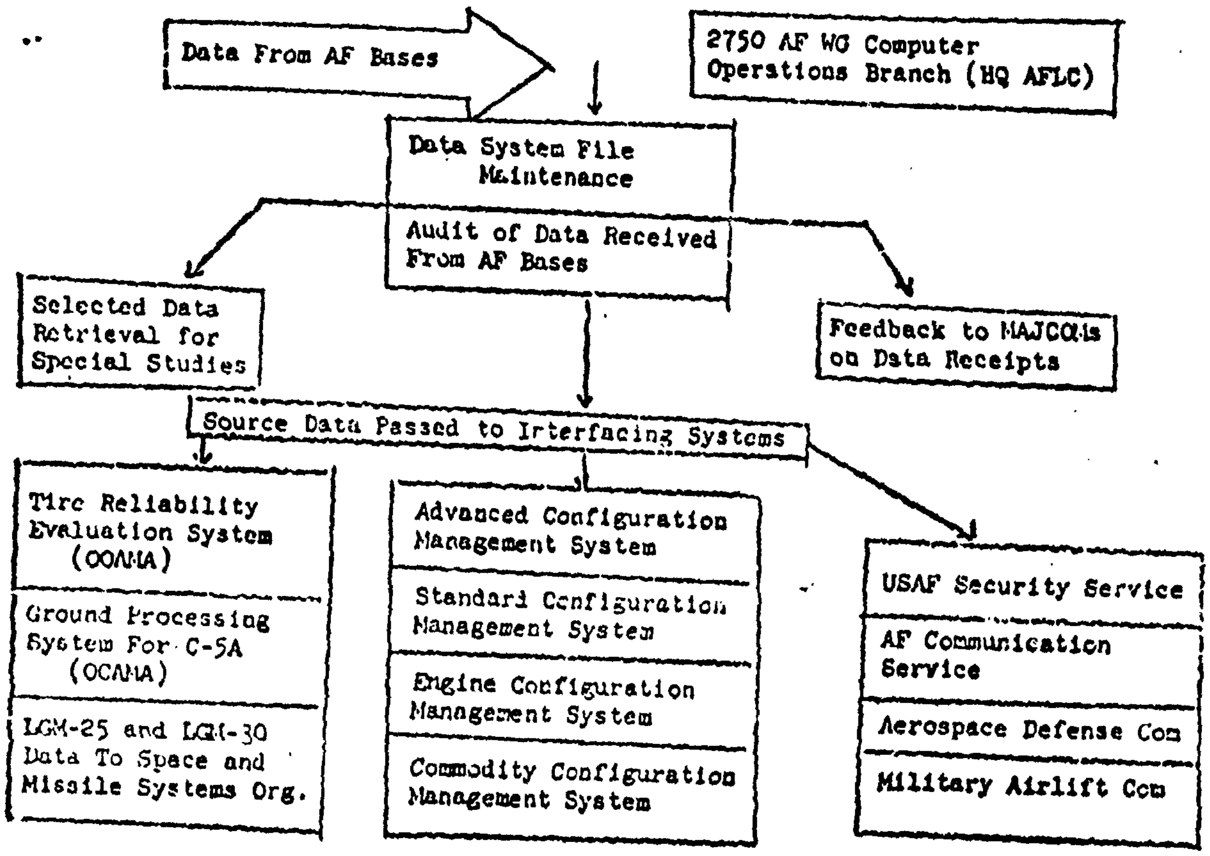


Figure 3-2

AFLC DO56 MONTHLY COMPUTER PROCESSES

Data From DO56 Weekly Processes

Source Data to Interfacing Systems

- Logistic Cost Ranking System Operating at Sacramento ALC
- Flight Safety Prediction Technique Operating at San Antonio ALC
- Analytical Interval Determination For Depot Level Maintenance
- Department of Defense Contractors

Data From Interfacing Systems

- Part Number to Stock Number Identification, Unit Price and AF Mgt Activity From Federal Cataloging System
- Identification of the Item Manager Technician and Division Within the AFLC Air Materiel Area
- Flying Hours, Inventory, Sorties and Landing From the Aircraft Status Reporting System
- Accident, Incident and Emergency Unsatisfactory Materiel Report Data From the AFLC AF Material Safety Office

DO56 Output Reports

- DO56 Data System Evaluation Reports
- Reports Designed for Evaluation of Hardware and Maintenance Performance Related to Individual Weapons and Equipment
- Reports Designed for Evaluation of Hardware and Maintenance Performance Related to Recoverable Items
- Precision Measurement Equipment Calibration Interval Analysis
- Selected Data Retrieval for Special Studies

Figure 9-3

d. Use Factor (K_1). This is a ratio of actual use time of individual Work Unit Codes to flying hours.

e. Mean Time Between Failure Occurrence (MTBF).

$$MTBF = \frac{\text{End Item Operating Time}^* \times K_1 \times QPA}{\text{Quantity of Failures}}$$

*End item operating time is determined as follows:

For aircraft—active aircraft inventory flying time from AFM 65-110.

For other equipment—Active inventory flying time from AFM 65-110.

f. Mean Time Between Maintenance Occurrence (MTBM).

$$MTBM = \frac{\text{End Item Operating Time}^* \times QPA}{\text{Quantity of Data Maintenance Occurrences}^*}$$

*All types of actions described in paragraph 9-6a.

g. Action Limit (AL). This is a form of failure limit expressed in MTBF (hours) and used in the computer program to compare current failure rates with past history for the same item.

h. Failure Limit. This is the acceptable quantity of failures of an item for a 30-day period. It is assigned by the system manager and used in the computer program to compare current period failures with past history for the same item.

9-7. DO56 OUTPUT REPORTS. Selected reports containing R and M related data are identified and briefly described in the following subparagraphs.

a. Selected Work Unit Code, Control Identifier, RCS: LOG-MMO(AR)7166. This report provides summarized information on Work Unit Codes within a weapon for the current reporting period that breeched either the Action Limit or Failure Limit; had Emergency Unsatisfactory Materiel Reporting; were high man-hour consumers or were high corrosion repair man-hour consumers. This report is used as a management reference to identify items that may warrant detail study and evaluation. Sample report Figure 9-4.

b. Detail Maintenance Actions for Selected Work Unit Codes, RCS: LOG-MMO(AR)7167. This report provides one to twelve months of "on" equipment information on Work Unit Codes within a weapon for detail studies. It is available only on special inquiry and can be limited in data presentation by selective retrieval options. (Sample Report Fig. 9-5.)

c. Detail Shop Actions for Selected Work Unit Codes, RCS: LOG-MMO(AR)7168. This report is a companion report to paragraph 9-7b and provides detail information from supporting repair shops on reparable items removed from a weapon. It also displays parts replaced during shop repair. (Sample Report Fig. 9-6.)

d. Summarized Maintenance Actions for Selected Work Unit Codes: RCS: LOG-MMO(AR)7169. This report provides the same type of information as described in paragraphs 9-7b and c but with lesser detail. It is produced when the Action or Failure Limit is breeched and also by special inquiry using selective retrieval routines. (Sample Report Fig. 9-7.)

e. Maintenance Actions, Man-hours and Aborts by Work Unit Code, RCS: LOG-MMO(AR)7170. This report provides six months of selected information by month on every reportable Work Unit Code assigned to a particular weapon or equipment. This information includes aborts, failures, maintenance actions, MTBF, MTBM and man-hours. Both "on" and "off" equipment data are considered for display in this report (except for some types of AGE, trainers and munitions). (Sample Report Fig. 9-8.)

f. Aborts and Degraded Alerts, RCS: LOG-MMO(AR)7171. This report provides current month detail information on Work Unit Codes and part numbers causing aborts, mission failures and degraded alerts. For ground equipment, this report identifies items causing equipment downtime. (Sample Report Fig. 9-9.)

g. Materiel Safety Deficiency Report, RCS: LOG-MMO(M)7178. This report provides twelve months of selected information for Work Unit Codes applicable to a Mission Design Series aircraft that have been reported as contributing to an accident or incident or have been the subject of an Emergency Unsatisfactory Materiel Report. Any of the above events having occurred within the past twelve months and recorded in the DO56 system, drives the computer to display failure rate, trending and predictive maintenance experience data in this report as well as the quantity of hazard conditions reported. (Sample Report Fig. 9-10.)

h. Work Unit Code Corrosion Summary, RCS: LOG-MMO(AR)7179. This report provides three months of information on a weapon or equipment identifying Work Unit Codes, number of units, man-hours and labor cost for corrective maintenance due to corrosion. The 25 Work Unit Codes incurring the highest corrosion repair cost are rank ordered and displayed separately in the report for ease of identification. (Sample Report Fig. 9-11.)

i. System, Subsystem Corrosion Summary, RCS: LOG-MMO(AR)7180. This report is produced as a comparison report to h above using the same three months of corrosion repair data except that the information is summarized to system/subsystem level and base location. (Sample Report Fig. 9-12.)

j. System, Subsystem, Work Unit Code Failure Summary, RCS: LOG-MMO(AR)7183. This report provides twelve months of information related to current quarter experience for systems, selected subsystems and Work Unit Codes on an aircraft. The data displayed is rank ordered by system, subsystem within system and Work Unit Code within subsystem based on the quantity of failures incurred. Information displayed includes the quantity of failures, MTBF, and a ratio of current quarter to the last twelve months experience. (Sample Report Fig. 9-13.)

k. Failure Rate Data for Selected Work Unit Codes, RCS: LOG-MMO(AR)7184. This report provides twelve months of information quarterly when the Action Limit is breeched and also by special in-

Copy available to DTIC does not permit fully legible reproduction

quiry using selective retrieval routines. Information displayed includes current quarter, previous quarter and 12-month MTBF, quarter to 12 month ratio and data groupings by when discovered, action taken, how malfunctioned and base location. (Sample Report Fig. 9-14.)

l. Maintenance Man-hours per Flying Hour by Weapon, Command and System, RCS: LOG-MMO(AR)7185. This report provides 12 months of information updated quarterly. The data displayed and the related computations are as indicated in the report title. (Sample Report Fig. 9-15.)

m. Maintainability Reliability Summary, RCS: LOG-MMO(AR)7220. This special inquiry report provides 12 months of information on Work Unit Codes within an aircraft. Information displayed includes failure, maintenance action, abort and man-hour rates as well as the most predominate malfunction modes. (Sample Report Fig. 9-16.)

n. Selected Part Number Action Summary, RCS: LOG-MMO(AR)7188. This report provides 12 months of information on a recoverable line item of supply (part number worldwide) regardless of its installed use environment. It is produced when the computed failure limit for an item (Federal Stock Number) is breeched and also by special inquiry. The information displayed does not reflect maintenance required while installed in a weapon or equipment. It is limited to "off" equipment (shop and depot) repairs. (Sample report Fig. 9-17.)

o. Maintenance Actions for Selected FSN Numbers, RCS: LOG-MMO(AR)7189. This report provides six months of "off" equipment (shop and depot repair) information on a recoverable item. Information displayed includes quantities of maintenance actions, malfunction modes, and base location. It is produced when the computed failure limit for an item (Federal Stock Number) is breeched and also by special inquiry.

p. Parts Replaced During Field or Depot Repair, RCS: LOG-MMO(AR)7190. This report is produced on the same criteria as above displaying six months of parts replaced during repair of items identified in the RCS: LOG-MMO(AR)7189. Information also displays quantity and reason for replacement. (Sample report Fig. 9-18.)

TABLE OF CONTENTS

ACTION TAKEN CODES

CODE	DESCRIPTION
A	BENCH CHECKED AND REPAIRED. THIS CODE WILL BE ENTERED WHEN BENCH CHECK AND REPAIR OF ANY ONE ITEM IS ACCOMPLISHED AT THE SAME TIME (ALSO SEE CODE F)
B	BENCH CHECKED SERVICEABLE (NO REPAIR REQUIRED) THIS CODE WILL BE ENTERED WHEN THE ITEM IS BENCH CHECKED AND NO REPAIR WAS REQUIRED
C	BENCH CHECKED REPAIR DEFERRED. THIS CODE WILL BE ENTERED WHEN BENCH CHECK IS ACCOMPLISHED AND REPAIR ACTION IS DEFERRED (SEE CODE F)

ACTION TAKEN CODES

CODE	DESCRIPTION
A	BENCH CHECKED AND REPAIRED. THIS CODE WILL BE ENTERED WHEN BENCH CHECK AND REPAIR OF ANY ONE ITEM IS ACCOMPLISHED AT THE SAME TIME (ALSO SEE CODE F)
B	BENCH CHECKED SERVICEABLE (NO REPAIR REQUIRED) THIS CODE WILL BE ENTERED WHEN THE ITEM IS BENCH CHECKED AND NO REPAIR WAS REQUIRED
C	BENCH CHECKED REPAIR DEFERRED. THIS CODE WILL BE ENTERED WHEN BENCH CHECK IS ACCOMPLISHED AND REPAIR ACTION IS DEFERRED (SEE CODE F)

CODE	DESCRIPTION
D	BENCH CHECKED TRANSFERRED TO ANOTHER BASE OR UNIT. ITEM IS BENCH CHECKED AT A FORWARD OPERATING BASE, DISPERSED OPERATING BASE OR ENROUTE BASE AND IS FOUND UNSERVICEABLE AND TRANSFERRED TO A MAIN OPERATING BASE OR HOME BASE FOR REPAIR. THIS CODE WILL NOT BE USED FOR ITEMS RETURNED TO A DEPOT FOR OVERHAUL. THIS CODE WILL ALSO BE USED WHEN PME OR OTHER EQUIPMENT IS SENT TO ANOTHER BASE OR UNIT FOR BENCH CHECK, CALIBRATION OR REPAIR AND IS TO BE RETURNED, AND FOR ITEMS FORWARDED TO CONTRACTORS ON BASE LEVEL CONTRACTS
1	BENCH CHECKED NRTS (NOT REPAIRABLE THIS STATION REPAIR NOT AUTHORIZED). THIS CODE WILL BE ENTERED WHEN THE SHOP IS NOT AUTHORIZED TO ACCOMPLISH THE REPAIR. THIS CODE SHALL ONLY BE USED WHEN THE REPAIR REQUIRED TO RETURN AN ITEM TO SERVICEABLE STATUS IS SPECIFICALLY PROHIBITED BY CURRENT TECHNICAL DIRECTIVES. THIS CODE SHALL NOT BE USED DUE TO LACK OF AUTHORITY FOR EQUIPMENT, TOOLS, FACILITIES, SKILLS, PARTS, OR TECHNICAL DATA.
2	BENCH CHECKED NRTS LACK OF EQUIPMENT, TOOLS, OR FACILITIES. THIS CODE WILL BE ENTERED WHEN THE REPAIR IS AUTHORIZED BUT CANNOT BE ACCOMPLISHED DUE TO LACK OF EQUIPMENT, TOOLS OR FACILITIES. THIS CODE SHALL BE USED WITHOUT REGARD AS TO WHETHER THE EQUIPMENT, TOOLS, OR FACILITIES ARE AUTHORIZED OR UNAUTHORIZED
3	BENCH CHECKED NRTS LACK OF TECHNICAL SKILLS. THIS CODE WILL BE ENTERED WHEN REPAIR CANNOT BE ACCOMPLISHED DUE TO LACK OF TECHNICALLY QUALIFIED PEOPLE
4	BENCH CHECKED NRTS LACK OF PARTS. THIS CODE WILL BE ENTERED WHEN PARTS ARE NOT AVAILABLE TO ACCOMPLISH REPAIR
5	BENCH CHECKED NRTS SHOP BACKLOG. THIS CODE WILL BE ENTERED WHEN REPAIR CANNOT BE ACCOMPLISHED DUE TO EXCESSIVE SHOP BACKLOG
6	BENCH CHECKED NRTS LACK OF TECHNICAL DATA. THIS CODE WILL BE ENTERED WHEN REPAIR CANNOT BE ACCOMPLISHED DUE TO LACK OF MAINTENANCE MANUALS, DRAWINGS, ETC. WHICH DESCRIBE DETAILED REPAIR PROCEDURES AND REQUIREMENTS
7	BENCH CHECKED NRTS EXCESS TO BASE REQUIREMENTS. THIS CODE WILL BE ENTERED WHEN REPAIR WILL NOT BE SCHEDULED FOR

ACTION TAKEN CODES (CONT)

CODE	DESCRIPTION (CONT)
7	BENCH CHECKED NRTS EXCESS TO REQUIREMENTS (CONT)
	SHOP REPAIR DUE TO ITEM BEING EXCESS TO BASE REQUIREMENTS
8	BENCH CHECKED RETURNED TO DEPOT RETURNED TO DEPOT BY DIRECTION OF SYSTEM MANAGER (SM) OR ITEM MANAGER (IM). USE ONLY WHEN ITEMS THAT ARE AUTHORIZED FOR BASE LEVEL REPAIR ARE DIRECTED TO BE RETURNED TO DEPOT FACILITIES BY SPECIFIC WRITTEN OR VERBAL COMMUNICATION FROM THE IM OR SM OR WHEN ITEMS ARE TO BE RETURNED TO DEPOT FACILITIES FOR MODIFICATION IN ACCORDANCE WITH A TIME COMPLIANCE TECHNICAL ORDER (TCTO) OR AS UN EXHIBITS
9	BENCH CHECKED CONDEMNED THIS CODE WILL BE ENTERED WHEN THE ITEM CANNOT BE REPAIRED AND IS TO BE PROCESSED FOR CONDEMNATION RECLAMATION OR SALVAGE. THIS CODE WILL ALSO BE USED WHEN A "CONDEMNED" CONDITION IS DISCOVERED DURING FIELD MAINTENANCE DISASSEMBLY OR REPAIR
E	INITIAL INSTALLATION THIS CODE WILL BE USED FOR INSTALLATION ACTIONS THAT ARE NOT RELATED TO A PREVIOUS REMOVAL ACTION SUCH AS INSTALLATION OF ADDITIONAL EQUIPMENT OR INSTALLATION OF AN ITEM TO REMEDY A SHIP SHORT CONDITION. THIS CODE WILL BE USED ONLY FOR EQUIPMENT MANAGED UNDER THE ADVANCE CONFIGURATION MANAGEMENT SYSTEM. REFERENCE T.O.'S 00 20 2 3 00 20 2 5 AND 00 20 2 7. MUST BE USED WITH HOW MAL CODE 799
F	REPAIR THIS CODE WILL NOT BE USED TO CODE "ON EQUIPMENT" WORK IF ANOTHER CODE WILL APPLY. WHEN IT IS USED IN A SHOP ENVIRONMENT THIS CODE WILL DENOTE REPAIR AS A SEPARATE UNIT OF WORK AFTER A BENCH CHECK. SHOP REPAIR INCLUDES THE TOTAL REPAIR MAN HOURS AND INCLUDES CLEANING DISASSEMBLY INSPECTION ADJUSTMENT REASSEMBLY AND LUBRICATION OF MINOR COMPONENTS INCIDENT TO THE REPAIR WHEN THESE SERVICES ARE PERFORMED BY THE SAME WORK CENTER. FOR PRECISION MEASUREMENTS EQUIPMENT THIS CODE WILL BE USED ONLY WHEN CALIBRATION OF THE REPAIRED ITEM IS REQUIRED (SEE CODE G)
G	REPAIR AND/OR REPLACEMENT OF MINOR PARTS HARDWARE AND SOFTGOODS (SEALS GASKETS ELECTRICAL CONNECTIONS FITTINGS TUBING HOSE WIRING FASTENERS VIBRATION ISOLATORS BRACKETS ETC) WORK UNIT CODES DO NOT COVER MOST NON REPAIRABLE ITEMS. THEREFORE WHEN ITEMS SUCH AS THOSE IDENTIFIED ABOVE ARE REPAIRED OR REPLACED THIS ACTION TAKEN CODE WILL BE USED. WHEN THIS ACTION TAKEN CODE IS USED THE WORK UNIT CODE WILL IDENTIFY THE ASSEMBLY BEING SERVICED OR MOST DIRECTLY RELATED TO PARTS BEING REPAIRED OR REPLACED. FOR EXAMPLE IF AN ELECTRICAL CONNECTOR WAS REPAIRED AND WAS ATTACHED TO A RADIO TRANSMITTER THE WORK UNIT CODE FOR THE TRANSMITTER WOULD BE USED WITH THIS ACTION TAKEN CODE. FOR PRECISION MEASUREMENT EQUIPMENT THIS CODE WILL BE USED FOR REPAIRS THAT DO NOT REQUIRE CALIBRATION OF THE REPAIRED ITEM (SEE CODE F)

ACTION TAKEN CODES (CONT)

CODE	DESCRIPTION (CONT)
H	EQUIPMENT CHECKED NO REPAIR REQUIRED (FOR "ON EQUIPMENT" WORK ONLY) THIS CODE WILL BE USED FOR ALL DISCREPANCIES WHICH ARE CHECKED AND FOUND TO REQUIRE NO FURTHER MAINTENANCE ACTION. THIS CODE WILL BE USED ONLY IF IT IS DEFINITELY DETERMINED THAT A REPORTED DEFICIENCY DOES NOT EXIST OR CANNOT BE DUPLICATED. MUST BE USED WITH HOW MAL CODE 799, 812 OR 948
J	CALIBRATED NO ADJUSTMENT REQUIRED USE THIS CODE WHEN AN ITEM IS CALIBRATED AND FOUND SERVICEABLE WITHOUT NEED FOR ADJUSTMENT OR IS FOUND TO BE IN TOLERANCE BUT IS ADJUSTED MERELY TO PEAK OR MAXIMIZE THE READING. IF THE ITEM REQUIRES ADJUSTMENT TO ACTUALLY MEET CALIBRATION STANDARDS OR TO BRING IN TOLERANCE USE CODE K
K	CALIBRATED ADJUSTMENT REQUIRED USE THIS CODE WHEN AN ITEM MUST BE ADJUSTED TO BRING IT IN TOLERANCE OR MEET CALIBRATION STANDARDS. IF THE ITEM WAS REPAIRED OR NEEDS REPAIR IN ADDITION TO CALIBRATION AND ADJUSTMENT USE CODE F
L	ADJUST INCLUDES ADJUSTMENTS NECESSARY FOR SAFETY AND PROPER FUNCTIONING OF EQUIPMENT SUCH AS ADJUST BLEED BALANCE RIG FIT REROUTE, SEAT/RESEAT POSITION/REPOSITION OR ACTUATING RESET BUTTON SWITCH OR CIRCUIT BREAKER. FOR USE WHEN A DISCREPANCY OR CONDITION IS CORRECTED BY THESE TYPES OF ACTIONS. IF THE IDENTIFIED COMPONENT OR ASSEMBLY ALSO REQUIRES REPLACEMENT OF BITS AND PIECES AS WELL AS ADJUSTMENT ENTER THE APPROPRIATE REPAIR ACTION TAKEN CODE INSTEAD OF L
M	DISASSEMBLE THIS CODE WILL BE ENTERED FOR DISASSEMBLY ACTION WHEN THE COMPLETE MAINTENANCE JOB IS BROKEN INTO PARTS AND REPORTED AS SUCH. DO NOT USE FOR ON EQUIPMENT WORK
N	ASSEMBLE THIS CODE WILL BE ENTERED FOR ASSEMBLY ACTION WHEN THE COMPLETE MAINTENANCE JOB IS BROKEN INTO PARTS AND REPORTED AS SUCH. DO NOT USE FOR ON EQUIPMENT WORK
P	REMOVED THIS CODE WILL BE ENTERED WHEN AN ITEM IS REMOVED AND ONLY THE REMOVAL IS TO BE ACCOUNTED FOR. IN THIS INSTANCE RELATED OR ADDITIONAL ACTIONS WILL BE ACCOUNTED FOR SEPARATELY (ALSO SEE CODES Q R S T AND U). DO NOT USE FOR OFF EQUIPMENT WORK
Q	INSTALLED THIS CODE WILL BE ENTERED WHEN AN ITEM IS INSTALLED AND ONLY THE INSTALLATION ACTION IS TO BE ACCOUNTED FOR (ALSO SEE CODES E P R S T AND U). DO NOT USE FOR OFF EQUIPMENT WORK
R	REMOVE AND REPLACE THIS CODE WILL BE ENTERED WHEN AN ITEM IS REMOVED AND ANOTHER LIKE ITEM IS INSTALLED (ALSO SEE CODES T AND U). DO NOT USE FOR OFF EQUIPMENT WORK
S	REMOVE AND REINSTALL THIS CODE WILL BE ENTERED WHEN AN ITEM IS REMOVED AND THE SAME ITEM REINSTALLED (ALSO SEE CODES T AND

ACTION TAKEN CODES (CONT)

CODE	DESCRIPTION (CONT)
S	REMOVE AND REINSTALL (CONT)
	U). DO NOT USE FOR OFF EQUIPMENT WORK. MUST BE USED WITH HOW MAL CODE 800, 804 OR 805
T	REMOVED FOR CANNIBALIZATION THIS CODE WILL BE ENTERED WHEN A COMPONENT IS CANNIBALIZED. THE WORK UNIT CODE WILL IDENTIFY THE COMPONENT BEING CANNIBALIZED. DO NOT USE THIS CODE FOR OFF EQUIPMENT WORK. MUST BE USED WITH HOW MAL CODE 799.
U	REPLACED AFTER CANNIBALIZATION THIS CODE WILL BE ENTERED WHEN A COMPONENT IS REPLACED AFTER CANNIBALIZATION. DO NOT USE THIS CODE FOR OFF EQUIPMENT WORK. MUST BE USED WITH HOW MAL CODE 799.
V	CLEAN THIS CODE WILL BE ENTERED WHEN CLEANING IS ACCOMPLISHED TO CORRECT DISCREPANCY AND/OR WHEN CLEANING IS NOT ACCOUNTED FOR AS PART OF A REPAIR ACTION SUCH AS CODE F. INCLUDES WASHING ACID BATH BUFFING SAND BLASTING DEGREASING DECONTAMINATION ETC. CLEANING AND WASHING OF COMPLETE ITEMS SUCH AS GROUND EQUIPMENT, VEHICLES MISSILES OR AIRPLANES SHOULD BE RECORDED BY UTILIZING SUPPORT GENERAL CODES
X	TEST INSPECTION SERVICE THIS CODE WILL BE ENTERED WHEN AN ITEM IS TESTED OR INSPECTED OR SERVICED (OTHER THAN BENCH CHECK) AND NO REPAIR IS REQUIRED. THIS CODE DOES NOT INCLUDE SERVICING OR INSPECTION CHARGEABLE TO SUPPORT GENERAL WORK UNIT CODES.
Y	TROUBLESHOOT ENTER THIS CODE WHEN TIME EXPENDED IN LOCATING A DISCREPANCY IS GREAT ENOUGH TO WARRANT SEPARATING THE TROUBLESHOOT TIME FROM THE REPAIR TIME. USE OF THIS CODE NECESSITATES COMPLETION OF TWO SEPARATE LINE ENTRIES OR TWO SEPARATE FORMS ONE FOR THE TROUBLESHOOT PHASE AND ONE FOR THE REPAIR PHASE. WHEN RECORDING THE TROUBLESHOOT TIME SEPARATE FROM THE REPAIR TIME THE TOTAL TIME TAKEN TO ISOLATE THE PRIMARY CAUSE OF THE DISCREPANCY SHOULD BE RECORDED UTILIZING THE WORK UNIT CODE OF THE DEFECTIVE SUB SYSTEM OR SYSTEM. DO NOT USE FOR OFF-EQUIPMENT WORK
Z	CORROSION REPAIR INCLUDES CLEANING TREATING PRIMING AND PAINTING OF CORRODED ITEMS. THIS CODE SHOULD ALWAYS BE USED WHEN ACTUALLY TREATING CORRODED ITEMS EITHER ON EQUIPMENT OR IN THE SHOP. THE WORK UNIT CODE SHOULD IDENTIFY THE ITEM THAT IS CORRODED. USE SUPPORT GENERAL CODE FOR PAINTING OR CORROSION PREVENTIVE TREATMENT PRIOR TO AN ITEM BECOMING CORRODED

TYPE MAINTENANCE CODES

CODE	DESCRIPTION
**	TYPE MAINTENANCE CODES FOR AIRCRAFT, DRONES, INSTALLED ENGINES AND RELATED MOBILE TRAINING SETS (MTS) AND RESIDENT TRAINING EQUIPMENT (RTE). ENGINE SHOP CODES ARE INCLUDED FOLLOWING THIS LIST OF CODES.
A	SERVICE - INCLUDES ALL UNITS OF WORK ASSOCIATED WITH SERVICING, CLEANING AND MOVEMENT OF EQUIPMENT.
B	UNSCHEDULED MAINTENANCE - INCLUDES ALL UNITS OF WORK ACCOMPLISHED BETWEEN SCHEDULED INSPECTIONS EXCEPT AS PROVIDED IN PRECEDING CODE A, AND EXCLUDING ACCOMPLISHMENTS OF TCTO'S
C	BASIC POSTFLIGHT OR THRUFLIGHT INSPECTION - INCLUDES ALL UNITS OF WORK ACCOMPLISHED DURING ALL PHASES OF THE BASIC POSTFLIGHT OR THRU FLIGHT INSPECTION.
D	PREFLIGHT INSPECTION - INCLUDES ALL UNITS OF WORK ACCOMPLISHED DURING ALL PHASES OF A PREFLIGHT INSPECTION. FOR MOBILE TRAINING SETS AND RESIDENT TRAINING EQUIPMENT THIS INCLUDES ALL UNITS OF WORK ACCOMPLISHED DURING SCHEDULED INSPECTIONS SUCH AS DAILY SAFETY AND SERVICING INSPECTION, EXCLUDING PERIODIC INSPECTIONS.
J	CALIBRATION OF OPERATIONAL EQUIPMENT (NON PME) BY OWNING OR ASSISTING WORK CENTER - EXCLUDES CALIBRATION ACTIONS BY PME CALIBRATING WORK CENTERS (SEE T.O. 00-25-06-4-1 FOR TYPE MAINTENANCE CODES FOR PME)
P	PERIODIC, PHASED OR MAJOR INSPECTION - INCLUDES ALL UNITS OF WORK ACCOMPLISHED DURING LOOK AND FIX PHASES OF PERIODIC, PHASED OR MAJOR INSPECTIONS, EXCLUDING ACCOMPLISHMENT OF TCTO'S.
Q	FORWARD SUPPORT SPARES - INCLUDES ALL UNITS OF WORK PERFORMED BY ALL ACTIVITIES IN RECORDING IN SHOP MAINTENANCE ACTIONS ON MAC FORWARD SUPPORT SPARES, EXCLUDING ACCOMPLISHMENT OF TCTO'S.
R	DEPOT MAINTENANCE - INCLUDES ALL UNITS OF WORK ACCOMPLISHED WHEN DEPOT MAINTENANCE OR REHABILITATION IS PERFORMED, REGARDLESS OF LOCATION. EXCLUDES ACCOMPLISHMENT OF TCTO'S
S	SPECIAL INSPECTION - INCLUDES ALL UNITS OF WORK ACCOMPLISHED DURING ALL PHASES OF SPECIAL INSPECTIONS, EXCLUDING ACCOMPLISHMENT OF TCTO'S. INCLUDES ALL FUNCTIONAL CHECK FLIGHTS
T	TIME COMPLIANCE TECHNICAL ORDER (TCTO) - INCLUDES ACCOMPLISHMENT OF ALL TCTO'S
Y	AIRCRAFT TRANSIENT MAINTENANCE - INCLUDES ALL UNITS OF WORK ACCOMPLISHED ON/OR FOR TRANSIENT AIRCRAFT, EXCLUDING ACCOMPLISHMENT OF TCTO'S.

NOTE

SEE T.O. 00-25-06-2-1 FOR OFF EQUIPMENT SHOP TYPE MAINTENANCE CODES

WHEN DISCOVERED CODES

CODE	DESCRIPTION
A	BEFORE FLIGHT - ABORT - AIR CREW
B	BEFORE FLIGHT-NO ABORT-AIR CREW.
C	IN FLIGHT ABORT.
D	IN FLIGHT - NO ABORT
E	AFTER FLIGHT - AIR CREW.
F	BETWEEN FLIGHTS-GROUND CREW
G	GROUND ALERT - NOT DEGRADED
H	BASIC POSTFLIGHT INSPECTION
J	PREFLIGHT INSPECTION.
L	DURING TRAINING OR MAINTENANCE ON EQUIPMENT UTILIZED IN A TRAINING ENVIRONMENT (USE ONLY FOR CLASS II TRAINING EQUIPMENT). THIS CODE SHOULD BE USED WHEN RECORDING MAINTENANCE OR DISCREPANCIES ON CLASS II TRAINERS
M	PHASED INSPECTION
N	GROUND ALERT - DEGRADED
P	FUNCTIONAL CHECK FLIGHT.
Q	SPECIAL INSPECTION
R	QUALITY CONTROL CHECK.
S	DEPOT LEVEL MAINTENANCE.
T	DURING SCHEDULED CALIBRATION.
U	NON DESTRUCTIVE INSPECTION INCLUDES OPTICAL, PENETRANT, MAGNETIC PARTICLE, RADIOGRAPHIC, EDDY CURRENT, ULTRASONIC, SPECTROMETRIC OIL ANALYSIS, ETC.
V	DURING UNSCHEDULED CALIBRATION
W	IN SHOP REPAIR AND/OR DISASSEMBLY FOR MAINTENANCE.
X	ENGINE TEST STAND OPERATION.
Y	UPON RECEIPT OR WITHDRAWAL FROM SUPPLY STOCKS
Z	DURING OPERATION OF MALFUNCTION ANALYSIS AND RECORDING EQUIPMENT OR SUBSEQUENT DATA ANALYSIS
4	CORROSION CONTROL INSPECTION.

Table B-1. How Malfunctioned Codes – Numerical Listing

001 .... Cases
002 .... Open Filament or Tube Circuit
006 .... Low Gm or Emission
007 .... Arcing, Arced
008 .... Noisy
009 .... Microphonic
010 .... Poor or Incorrect Focus
020 .... Worn, Chafed or Frayed
025 .... Capacitance Incorrect
026 .... Conductance Incorrect
029 .... Current Incorrect
031 .... Fluctuates, Unstable or Erratic
035 .... Fails to Tune or Drifts
036 .... Incorrect Modulation
037 .... High Voltage Standing Wave Ratio
069 .... Flame-Out
070 .... Broken
080 .... Burned Out or Defective Lamp, Meter or Indicating Device
090 .... Improper Handling
088 .... Incorrect Gain
092 .... Submerged - Water, Solvent, Electronic Force, etc.
094 .... No Gain or Emission
101 .... Attack Display Malfunction
103 .... Loose or Damaged Bolts, Nuts, Screws, Rivets, Fasteners, Clamps or Other Common Hardware
105 .... Missing Bolts, Nuts, Screws, Rivets, Fasteners, Clamps, or Other Common Hardware
108 .... Broken, Faulty or Missing Safety Wire or Key
111 .... Burst or Ruptured
116 .... Cut
117 .... Deteriorated
127 .... Adjustment or Alignment Improper
130 .... Change of Value
135 .... Binding, Stuck or Jammed
142 .... Engine Removed, Excessive Maintenance
150 .... Chattering
154 .... Launch Damage
160 .... Contacts/Connection Defective
167 .... Torque Incorrect
169 .... Incorrect Voltage
170 .... Corroded
177 .... Fuel Flow Incorrect
181 .... Compression Low
190 .... Cracked
206 .... Accidental Explosion of, or Damage from, Onboard Munitions
230 .... Dirty, Contaminated or Saturated by Foreign Material
242 .... Failed to Operate or Function - Specific Reason Unknown
246 .... Improper or Faulty Maintenance
253 .... Misfires
255 .... No Output/Incorrect Output
277 .... Fuel Nozzle Coking
279 .... Spray Pattern Defective
290 .... Fails Diagnostic/Automatic (RADAR) Test
300 .... Grounded Electrically
301 .... Foreign Object Damage
302 .... Bird Strike Damage
314 .... Slow Acceleration
315 .... RPM Fluctuation or Incorrect
317 .... Hot Start
320 .... Excessive Rub
334 .... Temperature Incorrect
350 .... Insulation Breakdown
372 .... Metal on Magnetic Plug
374 .... Internal Failure
380 .... Compressor Damaged - Reason Unknown
381 .... Leaking - Internal or External
382 .... Liquid Lock
383 .... Lock on Malfunction
390 .... Maintenance Action Due to Lost in Flight Occurrence
396 .... Oil Breathing Excessive
398 .... Oil Consumption Excessive
410 .... Lack of, or Improper Lubrication
424 .... External Power Source
425 .... Nicked
447 .... Wrong Logic
450 .... Open
457 .... Oscillating
458 .... Out of Balance
464 .... Overspeed
469 .... Bushing Worn or Damaged
472 .... Fuse Blown or Defective Circuit Protector
475 .... Engine Failed to Start
481 .... Keyway or Spline Damaged or Worn
486 .... Turbine Damaged - Reason Unknown
503 .... Sudden Stop
513 .... Compressor Stall
518 .... Improper Routing
520 .... Pitted
525 .... Pressure Incorrect
537 .... Low Power or Thrust
540 .... Punctured
553 .... Does Not Meet Specification, Drawing, or Other Conformance Requirements (May only be used with When-discovered Code Y)
561 .... Unable to Adjust to Limits
567 .... Resistance Incorrect
583 .... Scope Presentation Incorrect or Faulty
585 .... Sheared
598 .... Auto Rotation RPM Incorrect (High/Low)
599 .... Travel or Extension Incorrect
601 .... Detonation
602 .... Failed or Damaged Due to Malfunction of Associated Equipment or Item.
603 .... Oil in Induction System
604 .... Manifold Pressure Beyond Limits
605 .... Crazed
606 .... Counter Run Off-Position Indicator
607 .... [illegible] Indication - Specific Reason Unknown
615 .... Shorted
617 .... Sulfidation
619 .... Shimmy Excessive
622 .... Wet/Condensation
625 .... Gating Incorrect
626 .... Inductance Incorrect
627 .... Attenuation Incorrect
629 .... Relay Malfunction - Replacement Not Required
631 .... Bias Voltage Incorrect
632 .... Expended (Charge, Battery, Fire Extinguisher, Etc.)
635 .... Sensitivity Incorrect
636 .... Time Delay Incorrect
637 .... Triggering Incorrect
649 .... Sweep Malfunction
651 .... Air in System
652 .... Automatic Align Time Excessive
653 .... Ground Speed Error Excessive
654 .... Terminal Error - CEP Excessive
655 .... Terminal Error - Range Excessive
656 .... Terminal Error - Azimuth Excessive
657 .... Distance Measurement Error - Navigation Equipment
658 .... Bearing Destination (Station) Error
660 .... Stripped
664 .... Tension Incorrect
667 .... Scraped, Severe
669 .... Potting Material Melting (Reversion Process)
690 .... Vibration Excessive
692 .... Video Faulty
693 .... Audio Faulty
694 .... Audio and Video Faulty
695 .... Sync Absent or Incorrect
697 .... Faulty Tape - Program or Checkout
698 .... Faulty Card - Program or Checkout
709 .... Administrative Condemnation
710 .... Bearing Failure or Faulty
712 .... Improper Diagnosis
716 .... Improper Response to Mechanical Input
719 .... Broken or Frayed Bonding or Ground Wire
720 .... Brake Temperature Excessive
721 .... Improper Response to Electrical Input
729 .... Decoupled
730 .... Loose
731 .... Battle Damage
746 .... Frequency Erratic or Incorrect
750 .... Missing
770 .... Slip Ring or Commutator Failure
780 .... Bent, Buckled, Collapsed, Dented, Distorted or Twisted
782 .... Tire Tread Area Defective - Use Cut, Delaminated, Punctured, Worn, etc., if applicable
783 .... Tire Sidewall Damaged or Defective
784 .... Tire Bead Area Damaged or Defective
785 .... Tire Inside Surface Damaged or Defective
793 .... No Defect - TCTO Etc. Received but None Supply or Parts Are Available to Supply
797 .... No Defect - Technical Order Previously Complied With
798 .... No Defect - Technical Order Not Applicable - Equipment to be Replaced, Modified or Not Installed
799 .... No Defect
800 .... No Defect - Component Removed and/or Reinstalled to Facilitate Other Maintenance
801 .... No Defect - Technical Order Compliance
802 .... No Defect - Partial Technical Order Compliance
803 .... No Defect - Removed for Time Change
804 .... No Defect - Removed for Scheduled Maintenance or Modification
805 .... No Defect - Items or Components Electrical, Hydraulic, Etc., Fuel, Oxygen, Oil, etc., Lines, Mechanical Linkage and Drive Servicing & Equipment Removed, Disconnected and or Installed Connected to Facilitate Other Maintenance.
812 .... No Defect - Indicated Defect Caused by Associated Equipment Malfunction
814 .... [illegible] Flow
816 .... Impedance Incorrect
[illegible]
839 .... Q Plus Incorrect
840 .... Delaminated
865 .... Protective Coating Scale and Missing or Defective
877 .... Transportation Damage
878 .... Weather Damage
896 .... [illegible]
900 .... Burned or Overheated
901 .... Intermittent
910 .... Chipped
911 .... Technical Order Not Complied with - TCTO Complied with in Error or Placed in Work in Error
916 .... Impending or Incipient Failure Indicated by Spectrometric Oil Analysis
917 .... Impending Failure or Latent Defect Indicated by Non-destructive Inspection (Do not use if other codes apply.)
931 .. A Accidental or Inadvertent Operation, Release or Activation ([illegible] if item was lost in flight.)
932 .... Does Not Engage, Lock or Unlock Correctly
935 .... Scored or Scratched
937 .... [illegible]
938 .... Power Supply [illegible]
939 .... Unable to Load Program
[illegible]
942 .... [illegible]
943 .... Data Error
944 .... Parity Error
946 .... [illegible]
947 .... Torn
948 .... No Defect Operator Error
949 .... [illegible]
955 .... [illegible] High Error Rate
956 .... [illegible]
957 .... No Display
958 .... Incorrect Display
959 .... Fails to Transfer to Redundant Equipment
961 .... High Anode Current
962 .... Low Power - Electronic
963 .... Broken Filament Cathode Terminal
964 .... Poor Spectrum
966 .... RF Window Seals Broken or Cracked
968 .... [illegible]
969 .... [illegible] Input Cavity
970 .... Coolant Loss
971 .... Cracked Cathode Bushing
972 .... Damaged Input Frame
973 .... Damaged Output Frame
974 .... Does Not Track Tuning Curve
975 .... Filament to Cathode Short
980 .... Frequency Instability
981 .... Frozen Tuning Mechanism
983 .... Grid to Cathode Short
984 .... Grid to Plate Short
985 .... High Body Current/Beam Interception
986 .... High Modulator Inverse
987 .... Input Pulse Distortion
988 .... Loss of Vacuum
989 .... Low Coolant Flow Rate
990 .... No Focus Current
991 .... Out of Band Frequency
992 .... Output Pulse Distortion
993 .... RF Drive Improper
994 .... RF Feed-Thru Attenuated/Distorted
995 .... RF Feed - Thru Completely Interrupted
996 .... RF Terminal Overheated
997 .... RF Window Burned

Table B-2. Typical Avionics Work Unit Codes for UHF Communications and Terrain Following Radar - F-111F

T.O. 1F-111F-06

WORK UNIT CODE	
63000	UHF COMMUNICATIONS
63AA0	RECEIVER-TRANSMITTER RT-749/ARC-109
63AAA	POWER SUPPLY 0635
63AAC	AMPLIFIER, RF, 0629
63AAE	MODULE, EXCITER, 0630
63AAF	TRANSLATOR, SIGNAL DATA, 0628
63AAG	SYNTHESIZER, ELECTRONIC FREQ. 0632
63AAJ	RECEIVER, RADIO-GUARD 0636
63AAL	AMPLIFIER, AF, 0633
63AAQ	MODULE, MODULATOR, 0631
63AAT	SUBASSY, RT 7933
63AAU	TUNER, RF 0616
63AAV	MODULE, DIGITAL DATA COMPARATOR 0637
63AAW	MOUNT MT-3322/ARC-109
63AA9	NOC
63AB0	CONTROL ARC-109
63AB9	NOC
	GENERAL
63ACA	ANTENNA SELECTOR C4608/ARC
63ACB	ANTENNA, UPPER
63ACC	ANTENNA, LOWER
63ACD	SWITCH, RF TRANSMITTER SA-521/A
63ACE	PANEL ASSY, ANTENNA SELECT
63AC9	NOC

T.O. 1F-111F-06

WORK UNIT CODE	
73000	BOMBING NAVIGATION
73K00	RADAR SET TERRAIN FOLLOWING
73KB0 •	ANTENNA-RECEIVER, AS-2136/APQ-128
73KBA	AMPLIFIER, DUAL IF
73KBB	AMPLIFIER, AUTOMATIC FREQUENCY CONTROL
73KBC	VIDEO PROCESSOR
73KBD	PHASE DETECTOR
73KBE	VIDEO SUBASSY, (PN 582966-1)
73KBH	SWITCH, WAVEGUIDE
73KBL	POWER SUPPLY, KLYSTRON
73KBM	OSCILLATOR, SELF-TEST
73KBN	ANTENNA ASSY
73KBP	RECEIVER DUPLEXER
73KBS	KLYSTRON & CONNECTOR ASSY
73KB9	NOC
73KC0 •	INDICATOR, TERRAIN FOLLOWING, IP-1012/APQ-134
73KCA	PANEL ASSY, FRONT
73KCC	INDICATOR ASSY NO. 1
73KCD	INDICATOR ASSY NO. 2
73KCE	INDICATOR ASSY NO. 3
73KCF	INDICATOR, AZIMUTH SERVO ASSY (A4)
73KCG	SELECTOR ASSY, RANGE
73KCH	SWEEP DRIVER AND VOLTAGE REGULATOR ASSY (A9)
73KCJ	FILTER ASSY
73KCK	ELECTRON TUBE AND DEFLECTION ASSY
73KCL	POWER SUPPLY, HIGH VOLTAGE
73KC9	NOC
73KD0 •	CONTROL, RADAR SET, C-7510/APQ-128
73KDA	RELAY ASSY
73KDB	DIODE ASSY
73KD9	NOC
73KE0 •	AMPLIFIER, POWER SUPPLY, AM-6915/APQ-128
73KEA	AMPLIFIER, ELEVATION
73KEB	AMPLIFIER, AZIMUTH
73KEC	PROGRAMMER, SCAN
73KED	POWER SUPPLY, PLUS 15 VDC
73KEE	POWER SUPPLY, MINUS 15 VDC
73KEF	SWITCH ASSY, POWER
73KEG	DIODE & CAPACITOR

T.O. 1F-111F-06

WORK UNIT CODE	
73000	BOMBING NAVIGATION
73KE0 •	AMPLIFIER, POWER SUPPLY, AM-6915/APQ-128 (CONT)
73KEH	SWITCH, STABILIZATION
73KEJ	AMPLIFIER, SCAN
73KEK	MONITOR, SHIFT
73KE9	NOC
73KF0 •	SYNCHRONIZER-TRANSMITTER SN-519/APQ-128
73KFA	SYNCHRONIZER ASSY
73KFB	MONITOR, POWER
73KFC	MODULATOR ASSY
73KF9	NOC
73KG0	EQUIPMENT RACK, ELECTRICAL
73KG9	NOC
73KH0	WAVEGUIDE ASSY
73KHA	WAVEGUIDE, UPPER
73KHB	WAVEGUIDE, LOWER
73KH9	NOC
73KK0	COMPUTER, TERRAIN FOLLOWING CP-917/APQ-128
73KKA	PANEL ASSY
73KKB	GENERATOR, RANGE
73KKC	GENERATOR, TEMPLATE
73KKD	COMPUTER, FLIGHT VECTOR
73KKE	MONITOR, INPUT SIGNAL
73KKF	GENERATOR, AURAL COMMAND
73KKG	CONVERTER, SYN ANALOG
73KKH	DRIVER, SELF-TEST
73KKJ	GENERATOR, TEST SEQUENCE
73KKK	MONITOR, SELF-TEST
73KKL	PEAK DETECTOR
73KKM	ALTIMETER OVERIDE
73KKN	DEMODULATOR, STICK POSITION
73KK9	NOC
73V00	ATTACK RADAR AN/APQ-144
73VA0 •	RECEIVER TRANSMITTER MODULATOR MD-8-3
73VAA	MODULATOR ASSY
73VAB	TRIGGER ASSY
73VAC	OVERLOAD I ASSY
73VAD	REGULATOR, ENERGY A
73VAE	FILTER, 3 PHASE RECTIFIER
73VAF	SWITCHING ASSY, LOGIC
73VAG	RECTIFIER ASSY, SI
73VAH	MAGNETRON ASSY
73VAJ	AMPLIFIER, ELECTRONIC CONTROL

APPENDIX B

The Operational Audit Technique

When there are task times and frequencies that can not be attained using other techniques, these estimates are based on the combined experience and background of the manpower management technician, the specialist, and supervisory personnel. Estimates are made at the highest level of activity that gives confidence in the validity of the estimate and requires the continuous use of defined work crews and equipment. Air Force Regulation 25-5, Volume II describes this method of work study.

It should be emphasized that other methods, work measurement or work sampling, are recommended whenever feasible. In some instances these traditional techniques provide back up and/or bias checks. Some of the tasks included in this study have been subjected to work study and to resultant times for these tasks were compared to the estimates provided by specialists. As discussed earlier (see page 25), either method produced nearly identical task time estimates.

In the conduct of these interviews it was necessary to assess the specialist and his degree of understanding of the research requirement and ability to give "average" task times. In some cases it was necessary to estimate shortest and longest times for a given task and then obtain an opinion as to whether most such tasks tend toward the high or low. However, this researcher found that each specialist quickly grasped the concept and provided realistic estimates whenever his/her experience included the particular task.

Although a completely "standard" survey form or technique was not possible due to the differences in background, knowledge and perception, the general technique illustrated by the example in this appendix was used with each interviewee. Each specialist was either contacted by the researcher initially or asked by his supervisor to help the researcher determine maintenance task times.

Due to the various conditions under which maintenance is performed and the wide variety of maintenance activities and experience this researcher does not recommend that a standard survey form or approach be developed. Current analysts working in this area have operations, maintenance, manpower, or engineering backgrounds. Most have a combination of them, and all are trained thoroughly before conducting the interviews. Also the analyst who conducts the operations audit is involved in all other phases of the study.

This analyst does recommend that further research be conducted to determine the number of duplicate interviews that are required to determine the variance of task time estimates. By duplicating the interviews, problems of bias or random error may be detected that were heretofore unknown.

For this study operational audits were conducted at Seymour Johnson Air Force Base during several visits during 1979. From the work unit code manual for the selected example aircraft each maintenance specialist identified all tasks for which his/her specialty is responsible. Each task was identified for the type of work (remove and replace, repair on aircraft, troubleshoot, inspect and verify, etc.) required when a write up (discrepancy) has occurred. The specialist was then asked to estimate the time required to complete each task when the work is performed by (1) 5-level and then (2) 3-level maintenance personnel. Maintenance crew size, rework probabilities, safety and other related information was also requested from each specialist.

Operational audit interviews were conducted with two or more specialist for each specialty. Usually, the shop chief or the most experienced non-commissioned officer (NCO) was interviewed first. Then some of the experienced specialists were interviewed in order to verify the task times. In all, nearly fifty specialist were interviewed during the operational audit process. All interviews took place in the maintenance shops or on the flight line.

Specialists were generally willing, even anxious, to be interviewed. When the proper rapport had been established the interviewees seem intent upon giving good (realistic) estimates for the task times in their specialty. They often seemed glad that someone was taking an interest.

The transcript of one of these interviews is included here as an example of the technique that was used to collect the task times for this research.

The following is the transcript of an interview by Captain Larry Howell with Master Sergeant Widumus who is Non-Commissioned Officer in Charge (NCOIC) of the Fire Control and Radar Section for F-4E aircraft at Seymour Johnson Air Force Base, North Carolina.

The interview was one of many conducted during June 1979 in support of a skill level effort study being conducted by Captain Howell.

H Hi. I'm Captain Larry Howell. I'm from Wright-Patterson Air Force Base and I'm here in connection with a study that seeks to determine the differences in aircraft maintenance performed by 3-level maintenance specialists as opposed to 5 or 7 level repairmen. One of our primary tools is a computer simulation model which we use to estimate sortie generation capability of a given maintenance operation.
The output of our model looks like this . . .
Some of the required inputs include the task times for each individual maintenance task and the probability or likeliness that the task will have to be reworked.

I need your help to go through the work unit code manual and determine all the tasks for which your shop is responsible, and your estimate of the time required for a 3, 5 or 7 level technician to perform the work. Which AFSCs (Air Force Specialty Codes) do you have in your shop?

W All the 321s.

H Which areas in the work unit code manual are you responsible for?

W We handle the 74s.

H Okay. Let's go through the manual and talk about each job. If you would read the five digit work unit codes and tell me what kind of job you do on each, whether it's a repair on the aircraft, remove and replace, troubleshoot, access or whatever. Then give me the time you think it would take an average 5-level and the average 3-level to do the job.

W Well, some of our 3-levels aren't checked out yet so they can't do some of the jobs without help.

H Okay, we'll have to assume that we are talking about 3-levels who are checked out, but are not ready to become 5-levels yet. How long does it take for a new 3-level to become a 5-level?

W It usually takes about a year; some a little more, a few upgrade in about eight or nine months.

H How long does it take to check a 3-level out in all the tasks that he will be expected to do?

W That depends on our workload. On the average, maybe a month or two.

H How much extra training do you have to do after a 3-level gets here from tech school?

W Some can do most everything the first time, but most need to be watched for a month or two.

H You mean a 5 or 7 level must instruct or help them the first few times they do each job?

W Yes. Maybe four or five times. That takes about a month or two to get all the jobs.

H Okay. Let's assume the 3-levels we are talking about have been here between two and seven months. You might tell me the shortest and longest times you would expect for each task as we go through the work unit code manual.

W Okay.

H What's the first work unit code?

W The 74BAO. That's usually an R&R (remove and replace).

H Okay, how long does it take a 5-level to R&R that item?

W We always send two men to do the job. That's for any of our jobs.

H Is that for safety, or because of weight or what?

W Yes, it's because one guy has to be free to handle the power cart, get tools, help lift things and act as a safety observer.

H Can you send two 3-levels to do the job?

W Yes, but we try to send one 5 or 7 level along with a 3-level so we can get training - get the 3-level checked out.

H Can two 5-levels do the job faster than one 3-level and one 5-level?

W No, not really. As long as there is at least one 5 or 7 level it doesn't matter what skill level the other guy is.

H Is that true for the first time the 3-level has been on the job or after he has been on a similar task several times?

W Well, it might take longer if it's his first time if the other guy takes time to explain everything.

H But once he has seen the job a few times, a 5 and a 3 level can do the job just as fast as two 5s?

W Right.

H What if one or both specialists are 7-levels?

W The same as two 5s or a 5 and a 3. You can only do the job so fast.

H Is this for most jobs or just the 74BAO?

W It's for all our jobs.

H Okay, let's go back to the work unit code manual and start with the 74BAO. It's an R&R task. How long for a team that includes a 5 or 7 level?

W That's about an hour and a half usually. Sometimes an hour, sometimes two hours, but usually an hour and a half. That's a good average time.

H How about if two 3-levels do the job?

W Probably two hours. They're scared they might mess something up. They use the tech order more too and it takes longer for them to find things in the T.O.

H Okay, two hours is the average for the 3-levels, and it takes a crew of two. What's the next work unit code?

W The 74BBO. That's about an hour and a half for the 5-level and probably two and a half for the 3-level.

H That's also an R&R and a crew of two?

W Yes. The 74BCO - we fix that on the aircraft sometimes. Say two and a quarter hours for the 5-level and three hours for the 3-level. All of our jobs use two men. If we R&R it, it is an hour and a half and two and a half. It's a bear to get out.

H Okay.

W The 74BDO. That's an R&R. Say one and a half and two.

H Okay. Let me know if there are any jobs that don't fit this pattern, if 7-levels would be faster or different troubleshoot times or access times.

W Most of our jobs are R&R. Some are repair on the aircraft. Whenever we have to troubleshoot, it takes the 3-levels longer. Probably half again as long for any of our jobs. Access and hook up of AGE (Aerospace

Ground Equipment - power supplies, lighting, aircarts, etc.) don't take any longer.

H How about inspection or verification tasks?

W That takes a 3-level twice as long, when he can do it, once he's checked out.

H Okay. Does the troubleshoot and inspection time increase hold for all jobs or are there some exceptions?

W Well, let's see (looking at work unit code manual). No, that's true for all our jobs. Now maybe electrics might have different times. Their jobs are more complicated.

H Okay. I'll use 50% time increase for 3-level troubleshoot and 100% time increase for verify. What job is next?

W The 74BEO. Say one and a half and two hours. It's R&R.

H Okay.

W 74BFO. For R&R, say two hours and three hours and for on aircraft two and a quarter and three hours.

H Okay.

W 74BGO. R&R, one and a half and two hours.

H Okay.

W 74BHO. Two and a half for 5-levels and three and a half for 3-levels if it's on aircraft, and two hours and three hours if it's R&R.

H Okay.

.

.

.

W The 74840. That's four hours and five hours. That's the last one.

H Okay. Are there any other tasks or exceptions that I should be aware of?

W No, not that I can think of. That's all the jobs we do. I hope that will help.

H Do you think any of the jobs are more likely to have to be reworked if 3-levels do the work?

W No, not really.

H How about safety? Is there a problem with safety violations when 3-levels do the job? I mean either flight or ground safety.

W No, not in this area.

H Okay that helps a lot. Thank you.

APPENDIX C

5-Level and 3-Level Task Times

This appendix contains the list of all tasks and task times for which 5-level and 3-level maintenance personnel are reported to have different task times. The task names come from the Work Unit Code Manual as described on page 34. The task times were developed through the operational audit technique as described on pages 24 through 27 and Appendix B.

For each work center included in this study an attempt was made to interview at least one 7-level specialist and one 5-level specialist. When available a 3-level specialist was also interviewed. Generally 5 and 7 level personnel were able to give estimates about all the tasks that are performed by their work center. The 3-level personnel could only give times for the limited number of tasks that they has experienced. Whenever possible interviews were conducted independently. Otherwise, one specialist would give an estimated time (to the analyst this often appears to be the specialist with the most experience in the particular task) and the other would agree or disagree. Without exception all the interviewees gave the same task time for 5 and 7 level

3-levels often differed from the estimates for 5 and 7 levels. When a 3-level was present, the 5 and 7 level specialist would often ask his/her opinion about particular jobs prior to estimating 3-level task times. In these cases the task times were considered a consensus opinion. Where interviews were conducted separately, the estimates were studied by the analyst and large differences settled by a consensus among the specialists after interviews were completed. In this particular study, no differences of greater than 10 percent were noted.

In this analysis 78 of the 2094 tasks were answered by 3-level specialist independent of 5 or 7 levels. The 3-level specialists were asked to estimate only 3-level tasks times. Only three of the estimated tasks times differed from the 5-level specialist's estimates of the 3-level tasks times, and then by only a quarter hour for each three hour task. Figure C-1 presents the summary of 3 level/5 level task time differences. Figure C-1 is then followed by a listing of task times for 5 level and 3 level specialists.

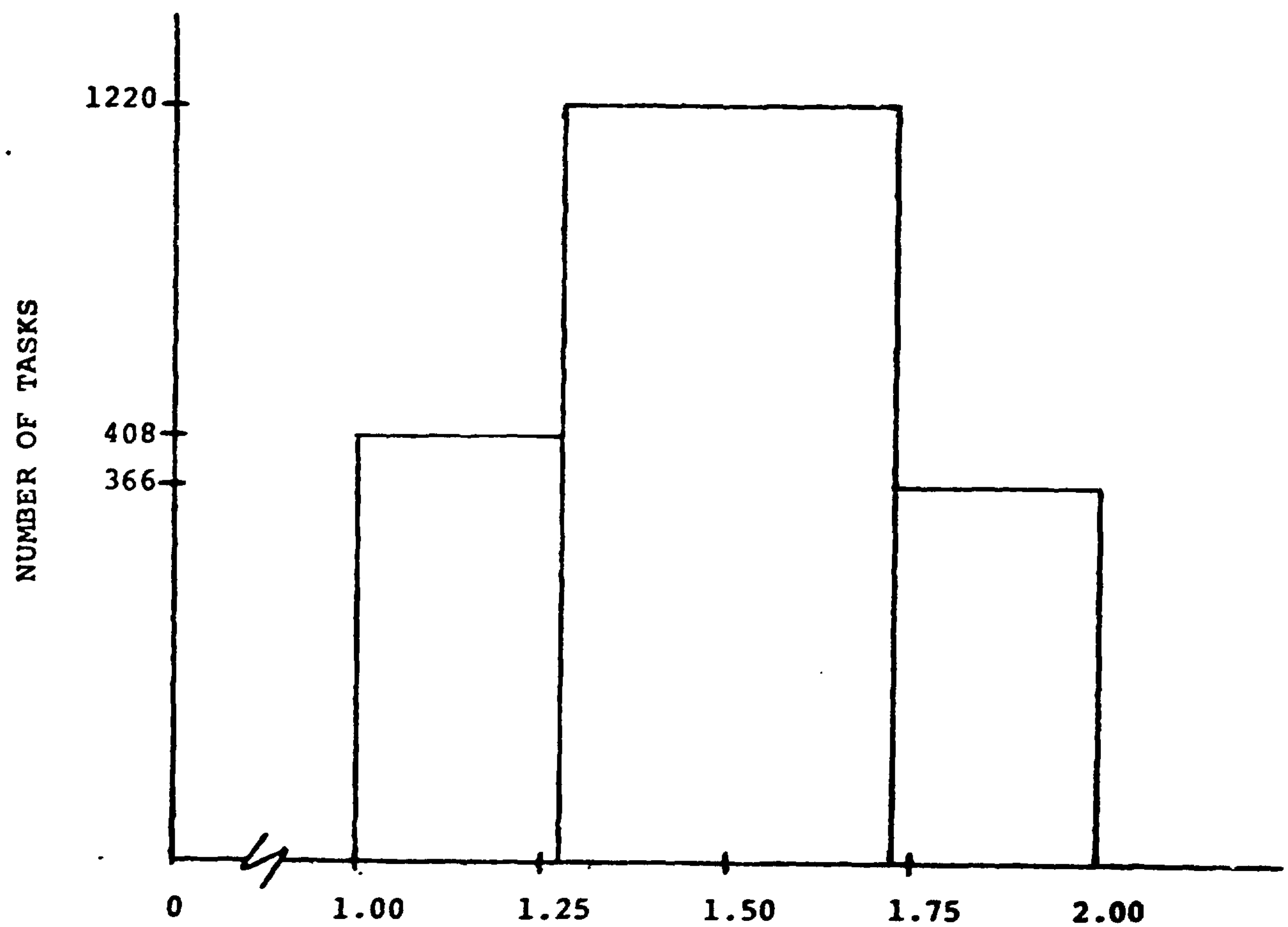


Figure 3-C. Task Time Factor Frequency
(3-Level/5-Level)

TASK NAME	5LVL TIME	3LVL TIME
A111AA	03.1	04.7
A111A1	02.9	04.4
A111BX	01.5	02.3
A111B1	01.5	02.3
A111B2	05.0	07.5
A111CX	03.7	05.6
A111CY	00.5	00.8
A111DX	01.6	02.4
A111FX	01.5	02.3
A111F1	01.5	02.3
A111F2	03.4	05.1
A111F3	00.5	00.8
A111GX	00.7	01.1
A111G1	06.0	09.0
A111G2	00.6	00.9
A111HX	05.2	07.8
A111H1	00.4	00.6
A111KX	00.5	00.8
A111K1	01.0	01.5
A111K2	02.5	03.8
A111LX	01.8	02.7
A111XX	06.0	09.0
A1119X	02.0	03.0
A11191	01.0	01.5
A112XX	01.5	02.3
A112X1	02.0	03.0
A112X2	00.9	01.4
A112X3	01.7	02.6
A112X4	08.0	01.2
A113XX	02.0	03.0
A113X1	01.3	02.0
A113X2	00.9	01.4
A113X3	02.7	04.1
A12110	02.5	08.8
A12120	02.2	03.3
A12201	02.8	04.2
A12202	00.9	01.4
A12203	01.0	01.5
A12310	03.9	05.9
A12330	02.4	04.8
A12331	02.0	03.0
A12332	00.9	01.4
A12333	01.1	01.7
A12340	03.0	04.5
A12350	09.1	02.6
A12360	03.0	04.5
A12361	01.0	01.5
A12362	00.8	01.2
A12370	03.1	04.6
A13100	02.5	03.7
A13210	01.7	02.6
A13211	01.0	01.5
A13212	02.0	03.0
A13213	02.0	03.0
A13220	01.0	01.5
A13221	00.8	01.2
A13222	04.4	06.6
A13230	03.4	05.1
A13231	04.0	06.0
A13240	03.5	05.3
A13290	01.3	02.0
A13310	03.0	04.5
A13311	02.5	03.8
A13312	03.0	04.5
A13320	03.0	04.5
A13321	00.8	01.2
A13322	04.9	07.4
A13341	[illegible]	00.8
A13342	04.8	07.2
A13343	01.7	02.6
A13410	06.5	09.8
A13420	02.2	03.3
A13421	01.5	02.3
A13441	00.5	00.8
A13442	02.0	03.0
A13443	05.1	07.7
A13444	00.1	00.2
A13500	04.8	07.2
A13501	05.0	07.5
A13502	01.9	03.0
A13503	02.1	03.2
A13504	02.4	03.6
A14100	03.0	04.5
A14101	07.5	11.3
A14102	01.4	02.6
A14210	05.9	08.9
A14220	03.1	04.7
A14221	00.5	00.8
A14230	02.0	03.0
A14231	01.8	02.7

TASK NAME	5LVL TIME	3LVL TIME
A14240	02.1	03.2
A14241	02.0	03.0
A14250	03.0	04.5
A14251	00.8	01.2
A14310	02.5	03.8
A14311	02.1	03.2
A14312	05.9	08.9
A14330	02.1	03.2
A14331	02.3	03.5
A14332	06.0	09.0
A14410	04.0	06.0
A14420	02.0	01.0
A14421	03.9	04.0
A14430	01.2	01.8
A14510	02.4	03.6
A14540	00.5	00.8
A14550	04.3	06.5
A14560	03.3	05.0
A14600	03.0	04.5
A14601	[illegible]	01.1
A14602	[illegible]	03.0
A14800	03.[illegible]	05.1
A14801	02.0	03.0
A23100	00.9	01.4
A23200	21.0	31.5
A23300	09.1	13.7
A23301	02.4	03.6
A23400	12.0	18.0
A23500	00.7	01.1
A23501	06.5	09.8
A23600	01.9	02.9
A23601	00.5	00.8
A23700	02.9	04.5
A23702	00.9	01.4
A23703	02.4	03.6
A23704	06.2	09.3
A23960	01.2	01.8
A23961	00.9	01.4
A23980	01.6	02.4
A23981	01.0	01.5
A41120	02.0	03.0
A41151	02.2	03.3
A41153	01.9	02.9
A41230	02.8	04.2
A41233	01.7	02.6
A41234	01.8	02.7
A42100	04.0	06.0
A42101	01.0	01.5
A42102	02.0	03.0
A42103	02.8	04.2
A42104	01.3	02.0
A42105	05.3	08.0
A42106	04.0	06.0
A42107	04.0	06.0
A42108	02.6	03.9
A42200	06.9	10.5
A42201	01.0	01.5
A42300	05.0	07.5
A42610	03.0	04.5
A42640	01.1	01.7
A44110	01.0	01.5
A44111	01.0	01.5
A44220	01.6	02.4
A44230	01.6	02.4
A45110	02.7	04.1
A45120	02.7	04.1
A45130	02.5	03.8
A45210	01.5	02.3
A46130	01.2	01.8
A46131	04.0	06.0
A46140	02.0	03.0
A46160	02.3	03.4
A462*0	02.0	03.0
A46230	02.5	03.8
A46231	02.3	03.4
A46232	02.0	03.0
A46233	01.0	01.5
A46300	02.0	03.0
A47100	02.2	03.3
A511*0	01.0	01.5
A511AJ	02.0	03.0
A511AL	00.9	01.9
A511A1	01.8	02.7
A512*0	01.7	02.6
A512AB	01.5	02.3
A513*0	05.0	07.5
A513B0	04.0	06.0
A52100	03.0	04.5
A522*0	01.6	02.4
A522B0	02.0	03.0

TASK NAME	5LVL TIME	3LVL TIME
A522E0	02.0	03.0
A71B10	06.0	09.0
A71B20	06.0	09.0
A71H10	02.0	00.6
A71H20	01.3	02.0
A71H21	02.5	03.8
A71H50	06.0	09.0
A71H60	06.0	09.0
A71L*0	06.0	09.0
A71L*1	01.0	01.5
A71LB0	04.2	06.3
A71LC0	05.0	07.5
A71LC1	02.3	03.5
A71LC2	00.8	01.2
A71LD0	02.0	03.0
A71LE0	08.0	12.0
A71LQ0	00.4	00.6
A71LX0	04.0	06.0
A71M*0	01.2	01.8
A71M*1	00.8	01.2
A71MA0	04.5	06.9
A71ME0	04.0	06.0
A71MG0	01.5	02.3
A71MH0	05.0	07.5
A71S00	02.1	03.2
A71T00	01.2	01.6
A71U00	02.8	04.2
A723A0	04.0	06.0
A723B0	02.0	03.0
A723E1	03.8	05.7
A72500	00.8	01.2
A731B0	03.1	04.7
A731C0	04.0	06.0
A731D0	02.3	03.5
A731E0	03.0	04.5
A731F0	01.5	02.3
A731H0	02.4	03.6
A735*0	00.8	01.2
A73510	02.0	03.0
A73520	04.0	06.0
A73530	06.0	09.0
A73531	00.1	00.2
A74B*0	01.1	01.7
A74BA0	02.0	03.0
A74BB0	03.0	04.5

TASK NAME	5LVL TIME	3LVL TIME
A74BC0	04.0	06.0
A74BC0	01.3	02.0
A74BD0	06.0	09.0
A74BF0	04.0	06.0
A74BG0	04.0	06.0
A74BH0	04.0	06.0
A74BJ0	03.0	04.5
A74BL0	03.0	04.5
A74BM0	02.0	03.0
A74BN0	05.0	07.5
A74BP0	06.0	09.0
A74BQ0	04.0	06.0
A74BR0	01.0	01.5
A74BS0	03.0	04.5
A74BU0	03.2	04.8
A74BV0	06.0	09.0
A74C*0	03.0	04.5
A74CA0	03.2	04.8
A74CB0	02.2	03.3
A74CB1	02.1	03.2
A74CC0	03.8	05.2
A74D*0	01.3	02.0
A74DA0	03.5	05.3
A74DB0	04.0	06.0
A74DC0	03.[illegible]	05.9
A74E00	01.0	01.5
A74E01	00.5	00.8
A74300	03.0	04.5
A748*	00.7	01.1
A74810	00.8	01.2
A74820	02.0	03.0
A74830	04.2	06.3
A74840	02.0	03.0
A74841	00.7	01.1
A75B00	02.2	03.3
A75B01	01.0	03.0
A76E*A	01.5	02.3
A76E*2	03.0	04.5
A76EA0	05.8	08.7
A76EB0	03.0	04.5
A76EC0	01.5	02.3
A76ED0	02.3	03.5
A76FA0	03.2	04.8
A77J*0	02.5	03.8
A77J2A	03.0	04.5

TASK NAME	5LVL TIME	3LVL TIME
A77J2K	03.5	05.3
A77J21	01.4	02.1
A77X*0	02.0	03.3
A77X6D	02.2	03.3
A93200	03.9	06.0
A97900	02.3	00.7
BBLDTK	03.0	04.5
BDWNL1	00.8	01.2
BDWNL2	00.4	00.6
BDOWNL	00.3	00.5
BECMLD	01.5	02.3
BHANGT	00.9	01.4
BHGM82	01.2	01.8
BLDGUN	00.4	00.6
BMISL3	01.5	02.3
BSTV03	00.4	00.6
BSTV04	00.5	00.8
B112XX	02.0	03.0
B12M82	01.0	01.5
B12200	00.1	00.2
B12201	02.1	03.2
B12330	01.2	02.3
B12360	00.8	01.2
B12361	01.3	02.0
B13210	00.3	00.5
B13220	00.5	00.8
B13221	00.6	00.9
B13230	02.2	03.3
B13231	01.3	02.0
B13250	04.7	07.1
B13252	01.5	02.3
B13260	04.9	07.4
B13262	01.5	02.3
B13290	01.0	01.5
B13310	00.5	00.8
B13320	01.0	01.5
B13331	05.0	07.5
B13332	00.6	00.9
B13340	00.6	00.9
B13341	01.0	01.5
B13410	01.5	02.3
B13420	01.0	01.5
B13430	01.0	01.5
B13431	00.8	01.2
B13441	04.5	06.8

TASK NAME	5LVL TIME	3LVL TIME
B13442	01.0	00.5
B13500	01.7	02.6
B13501	01.3	02.0
B13502	00.7	01.1
B13503	00.8	01.2
B14100	01.0	01.5
B14131	01.4	02.1
B14250	01.5	02.3
B14251	02.5	03.8
B14280	02.0	03.0
B14320	03.0	04.5
B14321	01.5	02.3
B14421	03.0	04.5
B14422	01.3	02.0
B14550	04.6	06.9
B14551	01.5	02.3
B14600	02.0	03.0
B14800	01.1	01.7
B14801	01.5	02.3
B23700	02.9	04.4
B23920	00.9	01.4
B23980	00.4	00.6
B23981	00.7	01.1
B41150	01.0	01.5
B41151	01.1	01.7
B41230	03.0	04.5
B42100	01.2	01.8
B42101	09.5	14.3
B42102	01.8	02.7
B42103	01.4	02.1
B42200	00.7	01.1
B42201	02.0	03.0
B42610	02.0	03.0
B42640	01.5	02.3
B45110	01.0	01.5
B45120	01.0	01.5
B45130	01.0	01.5
B46120	01.3	02.0
B46160	00.5	00.8
B462*0	00.5	00.8
B46210	00.8	01.2
B46220	00.9	01.4
B46230	01.0	01.5
B46231	00.3	00.5
B46420	01.5	02.3

TASK NAME	5LVL TIME	3LVL TIME
B47100	00.5	00.8
B511*0	01.0	01.5
B511AB	01.0	01.5
B511AD	01.0	01.5
B511AJ	01.0	01.5
B511AL	01.0	01.5
B512*0	01.0	01.5
B512AA	01.0	01.5
B512CL	01.0	01.5
B513*0	01.0	01.5
B513B0	01.0	01.5
B513E0	01.0	01.5
B513H0	02.0	03.0
B513X0	02.3	00.4
B522*0	01.0	01.5
B522B0	01.0	01.5
B522E0	01.7	02.6
B71B10	02.1	03.2
B71B10	01.0	01.5
B71B20	02.8	03.0
B71H10	01.0	01.5
B71H20	02.0	03.0
B71H50	04.0	06.0
B71H60	02.0	03.0
B71LB0	00.5	00.8
B71LC0	00.5	00.8
B71LD0	00.5	00.8
B71LE0	04.0	06.0
B71ME0	02.0	03.0
B71MG0	00.5	00.8
B71MH0	03.0	04.5
B71NA0	02.0	03.0
B71S00	01.3	02.0
B71T00	01.3	02.0
B71U00	01.6	02.4
B723A0	00.5	00.8
B723B0	00.5	00.8
B72500	00.5	00.8
B731*0	01.0	01.5
B731B0	01.5	02.3
B731C0	01.5	02.3
B731D0	02.2	03.3
B731E0	01.0	01.5
B731F0	01.0	01.5
B731G0	01.5	02.3

TASK NAME	5LVL TIME	3LVL TIME
B731H0	01.0	01.5
B731M0	01.0	01.5
B731N0	00.5	00.8
B732A0	01.5	02.3
B735*0	00.8	01.2
B73510	01.0	01.5
B73520	02.0	03.0
B73530	04.0	06.0
B74B*0	01.0	01.5
B74BA0	01.0	01.5
B74BB0	01.0	01.5
B74BC0	01.4	02.1
B74BD0	01.5	02.3
B74BF0	01.0	01.5
B74BG0	01.5	02.3
B74BH0	01.5	02.3
B74BJ0	01.0	01.5
B74BL0	01.0	01.5
B74BM0	00.8	01.2
B74BN0	01.0	01.5
B74BP0	02.0	03.0
B74BQ0	01.0	01.5
B74BS0	01.0	01.5
B74BU0	00.8	01.2
B74BV0	01.7	02.6
B74CB0	01.5	02.3
B74DA0	01.6	02.4
B74DB0	02.1	03.2
B74DC0	01.6	02.4
B74E00	00.8	01.2
B74300	01.0	01.5
B74810	01.5	02.3
B74820	01.0	01.5
B74830	01.2	01.8
B74840	01.5	02.3
B75B00	00.9	01.4
B76E*2	01.2	01.8
B76EA0	02.0	03.0
B76EB0	01.0	01.5
B76EC0	00.6	00.9
B76ED0	00.8	01.2
B76FA0	01.0	01.5
B77J2A	01.0	01.5
B77J2K	01.0	01.5
B77X*0	01.0	01.5

TASK NAME	5LVL TIME	3LVL TIME
H4610A	02.3	04.6
H46100	01.6	03.2
H46110	04.0	08.0
H46130	01.7	03.4
H4614B	01.5	03.0
H46140	02.6	05.2
H4615A	02.0	04.0
H46150	01.8	03.6
H46160	00.5	01.0
H462*0	03.0	06.0
H46210	02.7	05.4
H46230	02.0	04.0
H4630X	02.0	04.0
H46300	01.5	03.0
H46301	01.0	02.0
H46302	04.0	08.0
H464*0	01.5	03.0
H464*1	01.5	03.0
H464*2	04.3	08.6
H46420	02.0	04.0
H47100	00.5	01.0
H47101	00.8	01.6
H47200	01.5	03.0
H47201	00.8	01.6
H49100	02.0	04.0
H51100	01.5	05.0
H51200	02.0	04.0
H51300	02.0	04.0
H52100	02.0	04.0
H52200	02.0	04.0
H55100	00.5	01.0
H71B00	01.8	03.6
H71H00	02.5	05.0
H71L00	00.9	01.8
H71L01	01.0	02.0
H71M01	02.0	04.0
H71N00	01.0	02.0
H71U00	00.7	01.4
H72300	01.0	02.0
H72500	00.7	01.4
H73100	01.5	03.0
H73200	01.0	02.0
H73500	03.0	06.0
H74B00	00.7	01.4
H74C00	01.2	02.4

TASK NAME	5LVL TIME	3LVL TIME
H74D00	00.6	01.2
H74800	00.7	01.4
H75B00	01.0	02.0
H75B01	01.0	02.0
H75E00	01.3	02.6
H76E00	01.8	03.6
H76F00	00.7	01.4
H77X00	01.0	02.0
H77500	01.2	02.4
IAAB00	04.0	08.0
JCKGUN	00.4	00.6
JCODES	00.7	01.1
JCORIN	00.5	00.8
JCORR	02.5	03.8
JECMCK	00.2	00.3
JENGS1	00.6	00.9
JENGS2	00.3	00.5
JETCK0	00.3	00.5
JETCK1	00.3	00.5
JEORG1	00.1	00.2
JEORIN	00.1	00.2
JLUBE	00.7	01.1
JLOXSV	00.7	01.1
JPKCK1	00.2	00.3
JPOST2	02.0	03.0
JPREP1	01.0	01.5
JPRFL0	01.2	01.8
JPRFL1	01.2	01.8
JPRLC0	00.6	00.9
JPOST1	02.0	03.0
JTAXI0	00.2	00.3
JTAXOM	00.2	00.3
JTHRUF	01.0	01.5
JTOWAC	00.4	00.6
JTOWBK	00.5	00.8
MAAA00	01.5	02.8
MAAA01	02.4	03.6
MAAB00	01.3	02.0
MAAC00	02.2	03.3
MAAE00	02.9	04.4
MAC2A0	01.2	01.8
MAC2B0	02.0	03.0
MAC2C0	01.0	01.5
MAC2E0	04.0	06.0
MAC2E1	01.8	02.7

TASK NAME	5LVL TIME	3LVL TIME	TASK NAME	5LVL TIME	3LVL TIME
MAC2F0	00.8	01.2	M1120X	09.5	14.3
MAC2G2	00.7	01.1	M11201	01.1	00.3
MD6000	00.5	00.8	M11202	01.1	01.7
MNF200	00.5	00.8	M11203	04.0	06.0
MSLIS1	00.1	00.2	M11204	09.5	14.3
MTTU00	00.5	00.8	M11300	01.0	01.5
M111A0	00.8	01.2	M11301	02.0	03.0
M111A1	00.8	01.2	M11302	01.4	02.1
M111A2	01.4	02.1	M11303	01.1	01.7
M111B0	00.5	00.8	M11304	05.0	07.5
M111B1	01.0	01.5	M11305	01.0	01.5
M111B2	02.0	03.0	M11306	00.5	00.8
M111B3	02.7	04.1	M1211X	03.0	04.5
M111C0	00.5	00.8	M12110	01.0	01.5
M111C1	01.0	01.5	M12111	01.1	01.7
M111C2	01.5	02.3	M12112	01.0	01.5
M111D0	00.5	00.8	M12113	01.0	01.5
M111D1	01.0	01.5	M12114	01.0	01.5
M111D2	00.5	00.8	M12120	01.0	01.5
M111D3	00.9	01.4	M12121	01.0	01.5
M111F0	01.0	00.2	M12122	01.0	01.5
M111F1	00.6	00.9	M12123	01.0	01.5
M111F2	01.0	01.5	M12200	01.0	01.5
M111F3	01.9	02.9	M12201	01.0	01.5
M111G0	01.5	02.3	M12202	01.3	02.0
M111G1	01.0	01.5	M12203	01.0	01.5
M111G2	01.5	02.3	M12204	00.5	00.8
M111G3	01.5	02.3	M12310	02.2	03.3
M111H0	01.0	01.5	M12311	02.0	03.0
M111H1	01.8	02.7	M12312	01.2	01.8
M111H2	01.1	01.7	M12320	02.0	03.0
M111H3	01.0	01.5	M12321	02.0	03.0
M111K0	01.1	01.7	M12322	03.2	04.8
M111K1	01.6	02.4	M12323	00.8	01.2
M111K2	03.0	04.5	M12324	00.5	00.8
M111K3	00.7	01.1	M12325	00.8	00.3
M111L0	00.5	00.8	M12326	00.9	01.4
M111L1	01.0	01.5	M12330	00.8	01.2
M111L2	01.0	01.5	M12331	00.5	00.8
M111X0	03.1	04.7	M12332	01.0	01.5
M111X1	01.0	01.5	M12333	01.7	02.6
M111X2	01.1	01.7	M12334	02.6	03.9
M111X3	02.1	03.2	M12335	01.0	01.5
M11191	01.0	01.5	M12340	01.5	02.3
M11192	01.0	01.5	M12341	00.5	00.8

TASK NAME	5LVL TIME	3LVL TIME
M12342	02.0	03.0
M12343	05.0	07.5
M12344	01.2	01.8
M12345	00.5	00.8
M12350	00.6	00.9
M12351	01.0	01.5
M12352	08.0	12.0
M12353	01.3	02.0
M12360	00.6	00.9
M12361	00.5	00.8
M12362	01.1	01.7
M12370	02.0	03.0
M12380	01.0	01.5
M12381	00.5	00.8
M12382	01.0	01.5
M1239B	01.2	01.8
M12390	01.0	01.5
M12391	03.7	05.6
M12393	01.1	01.7
M12394	01.0	01.5
M12395	04.0	06.0
M12464	00.5	00.8
M12534	07.8	11.7
M1310X	02.0	03.0
M1310Y	01.6	02.4
M13100	00.9	01.4
M13101	03.0	04.5
M13102	02.0	03.0
M13103	00.5	00.8
M13104	01.2	01.8
M1321X	02.7	04.1
M13210	04.0	06.0
M13211	01.2	01.8
M13212	01.0	01.5
M13213	06.0	09.0
M13214	00.5	00.8
M13215	00.8	01.2
M13216	04.5	06.8
M13217	01.5	02.7
M13218	01.2	01.8
M13220	04.0	06.0
M13221	03.1	04.7
M13222	01.0	01.5
M13223	06.0	09.0
M13224	00.5	00.8
M13225	01.3	02.0
M13226	04.9	07.4
M13227	01.4	02.1
M1323X	02.0	03.0
M13230	02.0	03.0
M13231	02.5	03.8
M13232	01.0	01.5
M13233	01.4	02.1
M13234	04.0	06.0
M13235	01.2	01.8
M1324X	02.7	04.1
M13240	02.0	03.0
M13241	03.0	04.5
M13242	01.0	01.5
M13243	01.0	01.5
M13244	04.0	06.0
M13250	00.5	00.8
M13251	01.0	01.5
M13260	00.5	00.8
M13290	00.9	01.4
M13291	00.3	00.5
M13292	00.5	00.8
M13293	01.0	01.5
M1331X	02.7	04.1
M13310	02.7	04.1
M13311	00.5	00.8
M13312	01.0	01.5
M13313	01.2	01.8
M13314	01.0	01.5
M1332X	02.2	03.3
M1332Y	02.3	03.5
M13320	02.2	03.3
M13321	03.0	04.5
M13322	00.6	00.9
M13323	01.0	01.5
M13324	01.2	01.8
M13340	02.0	03.0
M13341	01.0	01.5
M13345	00.6	00.9
M134X0	00.9	01.4
M13410	01.7	02.6
M13420	01.0	01.5
M13421	01.0	01.5
M13422	01.0	01.5
M13430	01.1	01.7

TASK NAME	5LVL TIME	3LVL TIME
M13431	01.0	01.5
M13440	01.4	02.1
M13441	01.0	01.5
M13442	01.7	02.6
M13443	01.7	02.6
M13500	00.5	00.8
M13501	01.7	02.6
M13502	01.0	01.5
M13503	01.0	01.5
M13504	00.5	00.8
M13505	01.6	02.4
M14100	01.5	03.0
M14101	01.2	02.4
M14102	04.5	09.0
M14103	01.0	02.0
M14104	01.4	02.8
M142XX	01.2	00.3
M142XY	02.5	05.0
M142X0	01.2	02.4
M142X1	02.5	05.0
M14200	03.5	07.0
M14210	01.5	03.0
M14211	01.3	02.6
M14212	01.6	03.2
M1422X	01.7	03.4
M14220	02.5	05.0
M14221	00.8	01.6
M14222	04.3	08.6
M14223	01.0	02.0
M14224	00.3	00.6
M14231	02.7	05.4
M14232	02.2	04.4
M14233	01.1	02.2
M14234	00.8	01.6
M14240	01.0	02.0
M14241	00.8	01.6
M14242	01.1	02.2
M14243	02.8	05.6
M1425X	02.3	04.6
M14250	01.5	03.0
M14251	02.5	05.0
M14252	01.2	04.8
M1426X	02.0	04.0
M14260	02.0	04.0
M14261	01.6	03.2

TASK NAME	5LVL TIME	3LVL TIME
M14262	02.0	04.0
M14263	02.5	05.0
M1428X	01.3	02.6
M14280	02.0	04.0
M14281	01.3	02.6
M14282	00.5	01.0
M14310	00.5	01.0
M14311	00.5	01.0
M14312	01.9	03.8
M1432X	02.0	04.0
M14320	03.0	06.0
M14321	02.5	05.0
M14322	01.2	02.4
M1433X	05.0	10.0
M14330	00.9	01.8
M14331	01.0	02.0
M14332	05.0	10.0
M14333	01.0	02.0
M14334	01.2	02.4
M14350	00.7	00.2
M1436X	02.6	05.6
M14360	02.8	05.6
M14361	01.0	02.0
M14362	01.5	03.0
M14363	02.2	04.4
M14400	00.3	00.6
M14401	00.6	01.2
M14410	02.5	05.0
M14411	01.0	02.0
M14412	00.8	01.6
M14413	04.3	08.6
M1442X	03.1	06.1
M14420	02.0	04.0
M14421	01.9	03.8
M14422	05.0	10.0
M14423	01.0	02.0
M1443X	01.5	03.0
M1443Y	01.9	03.8
M14430	01.5	03.0
M14431	01.0	02.0
M14432	03.0	06.0
M14433	01.9	03.8
M14500	01.9	03.8
M14501	01.1	02.2
M14510	01.1	02.2

TASK NAME	5LVL TIME	3LVL TIME
M14511	01.1	02.2
M14512	01.0	04.0
M14520	03.7	06.4
M14521	01.9	03.8
M14522	01.0	02.0
M14523	00.8	01.6
M14532	00.3	00.6
M1454X	01.9	03.8
M14540	01.2	02.4
M14541	04.0	08.0
M14542	01.0	02.0
M14543	01.6	03.2
M1455X	01.9	03.8
M14550	01.4	02.8
M14551	01.9	03.8
M14552	01.6	03.2
M14553	03.2	06.4
M14560	01.8	03.6
M14561	00.3	00.6
M14590	02.9	05.8
M14591	01.1	02.2
M14610	00.5	01.0
M14611	00.5	01.0
M14612	02.2	04.4
M14620	02.0	04.0
M14621	01.0	02.0
M14800	05.4	10.8
M14801	02.4	04.8
M14802	02.5	05.0
M14803	02.0	04.0
M14804	02.0	04.0
M14805	00.3	00.6
M23000	01.5	03.0
M23001	01.2	02.9
M23002	01.0	02.0
M23003	01.0	02.0
M23004	01.6	03.2
M23005	01.4	02.8
M23006	01.0	02.0
M23007	01.2	02.4
M41110	01.0	01.5
M41111	00.7	01.1
M41120	02.2	03.3
M41130	01.5	02.3
M4114X	00.9	01.4

TASK NAME	5LVL TIME	3LVL TIME
M41140	00.9	01.4
M41150	01.2	01.8
M41151	01.0	01.5
M4121X	01.1	01.7
M41210	01.1	01.7
M41220	00.5	00.8
M41221	00.9	01.4
M4123X	01.6	02.4
M41230	01.0	01.5
M41231	01.2	01.8
M41233	01.3	02.0
M41300	01.0	01.5
M41301	01.2	01.8
M41400	03.0	04.5
M4210X	02.4	04.8
M42100	00.5	01.0
M42101	02.4	04.8
M42102	02.0	04.0
M42103	04.0	08.0
M42104	02.4	09.8
M42105	00.5	01.0
M42200	03.0	06.0
M42300	02.6	05.2
M42600	01.1	02.2
M42601	01.1	02.2
M42602	00.6	01.2
M42603	00.5	01.0
M44100	00.5	00.1
M44101	01.5	02.3
M44102	00.5	00.8
M44200	01.9	02.9
M44201	00.5	00.8
M44202	00.5	00.8
M44203	01.0	01.5
M45100	01.0	01.5
M45101	02.9	03.9
M45102	01.2	01.8
M45103	00.5	00.8
M45104	01.0	01.5
M45200	02.6	03.9
M45201	04.6	06.9
M4610A	02.8	04.2
M4610B	01.2	01.8
M4610C	01.5	02.3
M46100	01.0	01.5

TASK NAME	5LVL TIME	3LVL TIME
M4611A	02.0	03.0
M4611B	01.0	01.5
M46110	01.5	02.3
M4612A	00.9	01.4
M4612B	00.7	01.1
M46120	01.5	02.3
M4613A	01.5	02.3
M4613B	00.9	01.4
M4613C	01.0	01.5
M4613Z	02.0	03.0
M46130	01.0	01.5
M4614A	02.0	03.0
M4614B	02.5	03.8
M46140	01.0	01.5
M4615A	01.0	01.5
M4615B	00.9	01.4
M46150	01.0	01.5
M4616A	00.5	00.8
M4616B	01.0	01.5
M4616C	03.9	05.9
M46160	01.0	01.5
M4619B	01.0	01.5
M46199	01.8	02.7
M462*0	01.0	01.5
M462*1	09.1	13.7
M462*2	01.0	01.5
M462*3	01.4	02.1
M4621B	01.0	01.5
M46210	01.0	01.5
M46220	00.7	01.1
M46221	02.9	04.4
M4623A	02.0	03.0
M4623B	00.5	00.8
M4623C	01.1	01.7
M4623D	01.0	01.5
M46230	01.5	02.3
M46300	00.5	00.8
M46301	01.5	02.3
M46302	02.0	03.0
M46303	02.8	04.2
M464*0	03.9	05.9
M464*1	01.0	01.5
M464*2	01.5	02.3
M464*3	00.6	00.9
M46420	01.6	02.4

TASK NAME	5LVL TIME	3LVL TIME
M46421	01.2	01.8
M46422	00.5	00.8
M47100	00.5	00.8
M47200	01.2	01.8
M47201	00.9	01.4
M47202	00.5	00.8
M49100	01.0	01.5
M49101	01.0	01.5
M49102	00.5	00.8
M49103	01.4	02.1
M511*1	01.3	02.0
M511AB	01.0	01.5
M511AD	01.0	01.5
M511AJ	01.1	01.7
M511AL	01.0	01.5
M511A1	01.1	01.7
M511CA	01.0	01.5
M511C1	01.0	01.5
M512*0	00.5	00.8
M512*1	01.0	01.5
M512AA	00.8	01.2
M512AB	02.5	03.8
M512A1	01.0	01.5
M512A2	01.0	01.5
M512A3	01.0	01.5
M512A4	01.2	01.8
M512CL	00.5	00.8
M512C1	01.2	01.8
M512C2	01.0	01.5
M513*0	00.9	01.4
M513B0	00.5	00.8
M513B1	00.6	00.9
M513E0	00.5	00.8
M513F0	00.5	00.8
M513F1	01.5	02.3
M513H0	01.9	02.9
M513X0	01.0	01.5
M51300	02.0	03.0
M52100	02.0	03.0
M522B0	01.0	01.5
M522E0	02.0	03.0
M52200	02.0	03.0
M55100	01.5	02.3
M71BL0	00.5	00.8
M71B00	01.6	02.4

TASK NAME	5LVL TIME	3LVL TIME
M71B20	01.5	02.3
M71H00	03.0	04.5
M71H10	01.0	01.5
M71H20	02.0	03.0
M71H50	03.0	04.5
M71H60	02.5	07.8
M71H61	00.9	01.4
M71L*0	00.5	00.8
M71L*1	00.5	00.8
M71L*2	02.0	03.0
M71LC0	00.5	00.8
M71LD0	00.5	00.8
M71LD1	02.0	03.0
M71LE0	01.5	02.3
M71LQ0	03.5	05.3
M71LS0	01.0	01.5
M71LX0	01.5	02.3
M71L00	02.8	04.2
M71L20	02.0	03.0
M71L50	00.5	00.8
M71L70	00.5	00.8
M71L71	00.5	00.8
M71M*0	01.0	01.5
M71M*1	01.6	02.4
M71ME0	01.0	01.5
M71ME1	01.0	01.5
M71MG0	00.7	01.1
M71MH0	02.0	03.0
M71NA0	00.9	01.4
M71N00	01.0	01.5
M71R00	01.2	01.8
M71S00	01.2	01.8
M71T00	00.8	01.2
M71U00	00.6	00.9
M723*0	01.0	01.5
M723*1	01.8	02.7
M723A0	01.0	01.5
M723A1	01.8	02.7
M723B0	00.5	00.8
M723B1	00.6	00.9
M72300	01.0	01.5
M72500	01.5	02.3
M72501	00.9	01.4
M731*0	00.5	01.0
M731B0	00.4	00.8

TASK NAME	5LVL TIME	3LVL TIME
M731C0	01.1	02.2
M731D0	02.4	04.8
M731D1	00.9	01.8
M731E0	02.8	05.6
M731F0	01.5	03.0
M731G0	00.9	01.8
M731H0	00.5	01.0
M731H1	00.9	01.8
M731H2	00.2	00.4
M731M1	01.3	02.6
M731N0	00.6	01.2
M731N0	00.5	01.0
M73100	00.5	01.0
M732A0	00.5	01.0
M732A1	02.4	04.8
M732B0	01.0	02.0
M732C0	00.6	01.2
M735*0	00.5	01.0
M73500	01.1	02.2
M73510	01.0	02.0
M73520	02.0	04.0
M73530	03.0	06.4
M74B*0	01.1	02.2
M74BA0	01.0	02.0
M74BB0	01.0	02.0
M74BC0	01.0	02.0
M74BD0	01.0	02.0
M74BF0	02.0	04.0
M74BG0	01.0	02.0
M74BH0	01.0	02.0
M74BJ0	01.0	02.0
M74BL0	01.0	02.0
M74BM0	00.5	01.0
M74BN0	01.0	02.0
M74BP0	02.0	04.0
M74BQ0	01.0	02.0
M74BR0	01.5	03.0
M74BS0	01.0	02.0
M74BU0	01.0	02.0
M74BV0	01.5	03.0
M74B00	02.4	04.8
M74B01	01.3	02.6
M74C*0	00.7	01.7
M74CA0	01.4	02.8
M74CB0	00.5	01.0

TASK NAME	5LVL TIME	3LVL TIME
M74CC0	01.8	03.6
M74D*0	00.7	01.4
M74D*1	01.8	03.6
M74D*2	01.8	03.6
M74DA0	00.5	01.0
M74DB0	01.3	02.6
M74DC0	00.4	00.8
M74D00	00.7	01.4
M74E00	00.4	00.8
M74E01	01.0	02.0
M74300	00.5	01.0
M748*0	01.2	02.4
M74800	00.6	01.2
M74810	00.9	01.8
M74820	01.5	03.0
M74830	01.0	02.0
M74840	01.0	02.0
M75B00	01.2	02.4
M75B01	00.3	00.6
M75B02	00.3	00.6
M75B03	00.6	01.2
M75B04	00.5	01.0
M75B05	01.1	02.2
M75E00	02.3	04.6
M75E01	01.6	03.2
M751C0	00.5	01.0
M751C1	00.8	01.6
M751C2	01.3	02.6
M751C3	01.0	02.0
M751D0	00.8	01.6
M75101	03.4	06.8
M75600	00.7	01.4
M75800	00.9	01.8
M75900	02.0	04.0
M76E*1	01.1	02.2
M76E*2	01.3	02.6
M76E*3	01.0	02.0
M76EA0	01.8	03.6
M76EB0	02.0	04.0
M76EC0	01.3	02.6
M76ED0	00.9	01.8
M76E00	02.5	05.0
M76F*0	01.3	02.6
M76FA0	01.5	03.0
M76F00	01.3	00.3

TASK NAME	5LVL TIME	3LVL TIME
M76G00	02.0	04.0
M77J*1	00.5	01.0
M77J2A	01.2	02.4
M77J2K	00.9	01.8
M77J21	00.5	01.0
M77X*0	01.1	02.2
M77X6D	00.5	01.0
M97900	00.6	01.2
PAERO	01.5	02.3
PAER1	06.5	09.8
PAUTO	02.0	03.0
PCOMO	02.0	03.0
PCOR00	03.7	05.6
PCOR01	03.6	05.4
PCOR02	00.4	00.6
PCOR03	00.5	00.8
PCOR04	01.0	01.5
PCOR05	00.3	00.5
PCOR06	00.8	01.2
PCOR07	00.1	00.2
PCOR08	01.4	02.1
PCOR09	02.1	03.2
PCOR10	02.3	03.5
PCOR11	11.0	16.5
PCOR12	12.0	18.0
PCOR13	00.2	00.3
PDEPAN	02.0	03.0
PDFUL0	01.0	01.5
PDOPO	01.0	01.5
PECMO	00.5	00.8
PECSO	01.0	01.5
PEGRSO	06.0	09.0
PELECO	01.0	01.5
PELEC1	03.0	04.5
PENG1	06.0	09.0
PENG2	10.0	15.0
PFUEL0	01.0	01.5
PHHP06	33.0	49.5
PHP01	06.0	09.0
PHP03	16.5	24.8
PHYD0	02.5	03.8
PHYD1	06.0	09.0
PINS0	01.0	01.5
PINS1	02.0	03.0
PJACK	01.0	01.5

TASK NAME	5LVL TIME	3LVL TIME
PMACHO	02.5	03.8
PMUNO	01.0	01.5
PMUN1	05.0	07.5
PNDIO	01.0	01.5
PNDI1	02.0	03.0
PPHOTO	00.5	00.8
PPREP	00.5	00.8
PRPML1	03.0	04.5
PRPNL3	06.0	09.0
PRPNL6	07.0	10.5
PSAFE	00.3	00.5
PSMTLO	16.0	24.0
PTOW1	00.5	00.8
PWCSO	00.5	00.8
RAAA00	02.0	03.0
RAAB00	02.2	03.3
RAAC00	01.5	02.3
RAAE0C	04.3	06.5
RAC2A0	03.7	05.6
RAC2B0	01.5	02.3
RAC2C0	01.3	02.0
RAC2C1	02.5	03.8
RAC2E1	05.0	07.5
RAC2F0	02.2	03.3
RAC2G0	01.0	01.5
RLAU88	02.0	03.0
RMAU12	08.0	12.0
RMERS	06.0	09.0
RS238S	01.0	01.5
R111A0	00.5	00.8
R111A1	03.9	05.9
R111B0	01.0	01.5
R111B1	02.8	04.2
R111C0	01.0	01.5
R111C1	00.9	01.4
R111D0	00.7	01.1
R111F0	03.1	04.7
R111G0	03.0	04.5
R111H0	03.0	04.5
R111K0	03.1	04.7
R111L0	01.2	01.8
R111XX	09.1	14.2
R111X0	02.0	03.0
R111X1	02.0	03.0
R11190	01.8	02.7

TASK NAME	5LVL TIME	3LVL TIME
R11201	02.0	03.0
R1130X	02.0	03.0
R11300	02.0	03.0
R11301	06.0	09.0
R11302	01.8	02.7
R11303	06.0	09.0
R12110	02.0	03.0
R12111	01.0	01.5
R12112	10.0	15.0
R12200	01.0	01.5
R12201	01.0	01.5
R12310	02.0	03.0
R12310	04.0	06.0
R12311	00.5	00.8
R12312	03.3	05.0
R12320	06.9	10.4
R12321	06.0	08.0
R12330	02.8	04.2
R12331	02.5	03.8
R12340	01.5	02.3
R12341	02.4	03.6
R1235X	08.6	12.9
R12350	08.6	12.9
R12360	02.5	03.8
R12361	06.1	09.2
R12370	02.0	03.0
R12371	04.5	06.8
R12380	01.0	01.5
R12381	03.0	04.5
R12382	03.0	04.5
R12390	01.8	02.7
R12391	00.8	01.2
R1310X	04.0	06.0
R13100	01.0	01.5
R13101	04.0	06.0
R13102	02.8	04.2
R1321X	04.0	06.0
R1321Y	06.5	08.8
R13211	10.0	15.0
R1322X	02.9	04.4
R1322Y	04.3	06.5
R13220	04.0	06.0
R13221	10.0	15.0
R1323X	02.2	08.8
R1323Y	02.1	03.2

TASK NAME	5LVL TIME	3LVL TIME
R13230	02.2	03.3
R13231	03.0	04.5
R13232	02.5	03.8
R1324X	01.6	02.4
R1324Y	01.2	01.8
R13240	02.0	03.0
R13241	03.0	04.5
R13242	02.5	03.8
R13250	02.0	03.0
R13260	02.0	03.0
R13290	01.4	02.1
R13291	01.0	01.5
R1331X	05.2	07.8
R13310	05.2	07.8
R1332X	04.0	06.0
R13320	04.0	06.0
R13321	01.0	01.5
R13330	01.0	01.5
R1334X	03.7	05.6
R13340	03.7	05.6
R13341	01.6	02.4
R134X0	01.5	02.3
R1341X	06.0	09.0
R13410	06.0	09.0
R13420	02.5	03.8
R1343X	03.4	05.1
R13430	03.0	04.5
R13431	02.0	03.0
R13440	01.0	01.5
R13500	03.0	04.5
R13501	03.0	04.5
R14100	02.0	04.0
R14101	01.0	02.0
R14102	01.0	02.0
R14103	04.0	08.0
R142XY	02.5	05.0
R142X0	02.5	05.0
R1420X	06.0	12.0
R1420Y	06.0	12.0
R14200	06.0	12.0
R1421X	05.0	10.0
R14210	05.0	10.0
R1422X	04.2	08.4
R14220	04.2	08.4
R14230	02.5	05.0

TASK NAME	5LVL TIME	3LVL TIME
R14240	02.8	05.6
R14241	02.5	05.0
R14242	00.6	01.2
R1425X	03.1	06.2
R14250	03.1	06.2
R1426X	05.9	08.9
R14260	05.9	08.9
R1428X	02.5	05.0
R14280	02.5	05.0
R14310	02.7	05.4
R1432X	06.5	13.0
R14320	06.5	13.0
R1433X	03.5	07.0
R14330	00.8	01.6
R14331	03.5	07.0
R14332	01.9	03.8
R14333	03.0	06.0
R14350	02.5	05.0
R14351	06.2	12.4
R14400	01.0	02.0
R14410	00.8	01.6
R1442X	03.5	07.0
R1442Y	02.1	04.2
R14420	03.5	07.0
R14421	03.0	06.0
R14422	01.0	02.0
R1443X	03.0	06.0
R1443Y	03.9	07.8
R14430	03.0	06.0
R14431	05.0	10.0
R1454X	03.5	07.0
R14540	02.4	04.8
R14541	03.5	07.0
R1455X	04.3	08.6
R14550	01.0	02.0
R14551	03.0	06.0
R14552	03.0	06.0
R14560	03.0	06.0
R14610	01.5	03.0
R1462X	02.5	05.0
R14620	02.5	05.0
R14621	01.7	03.4
R14800	01.5	03.0
R14801	06.5	13.0
R14802	05.0	10.0

TASK NAME	5LVL TIME	3LVL TIME
R23000	07.4	14.8
R23001	01.0	02.0
R23002	04.0	08.0
R41110	02.0	03.0
R4112X	03.2	04.8
R41120	03.2	04.8
R4113X	02.0	03.0
R4113Y	01.8	02.7
R41130	02.0	03.0
R4114X	02.7	04.1
R41140	02.7	04.1
R41150	00.5	00.8
R41151	02.0	03.0
R4121X	02.0	03.0
R41210	02.0	03.0
R41211	02.4	04.1
R41220	00.6	00.9
R4123X	02.0	03.0
R41230	02.0	03.0
R41231	02.8	04.2
R41300	04.2	06.3
R41400	01.8	02.7
R4210X	02.4	03.6
R42100	02.0	03.0
R42101	03.0	04.5
R42102	02.0	03.0
R42103	03.0	04.5
R42104	02.5	03.8
R42105	02.1	03.2
R42106	03.0	04.5
R4220X	04.0	06.0
R4220Y	04.0	06.0
R42200	04.0	06.0
R42300	03.5	05.3
R42301	01.5	02.3
R42600	02.0	03.0
R42601	04.0	06.0
R44100	01.5	01.9
R44101	00.6	00.8
R44201	01.5	01.9
R44220	02.2	02.7
R4510X	01.5	02.3
R45100	01.5	02.3
R45101	04.2	06.3
R45200	02.5	03.8

TASK NAME	5LVL TIME	3LVL TIME
R45201	01.0	01.5
R46110	04.2	06.3
R46120	09.2	13.8
R46130	05.5	08.3
R4614A	02.0	03.0
R46140	03.5	05.3
R46150	06.2	09.3
R4616A	01.6	02.4
R46160	07.9	11.8
R4619A	03.0	04.5
R46199	03.0	04.5
R462*0	02.0	03.0
R46210	02.5	03.8
R46220	09.0	13.5
R4623B	01.7	02.6
R46230	02.0	03.0
R46300	03.5	05.3
R46302	01.8	02.7
R464*0	01.1	01.7
R464*1	01.4	02.1
R464*2	04.0	06.0
R46420	01.8	02.7
R46421	03.0	04.5
R47100	00.5	00.9
R47101	00.9	01.4
R47200	01.4	02.1
R47201	00.9	01.4
R49100	02.0	03.0
R511*0	01.5	02.3
R511AB	01.3	02.0
R511AD	01.3	02.0
R511AJ	01.3	02.0
R511AL	01.5	02.3
R511CA	01.5	02.3
R512*0	01.2	01.8
R512AA	00.9	01.4
R512AB	01.0	01.5
R512CL	01.0	01.5
R513*0	01.3	02.0
R513B0	01.5	02.3
R513E0	01.0	01.5
R513F0	03.0	04.5
R513H0	01.9	02.9
R513X0	01.5	02.3
R52100	01.0	01.5

TASK NAME	5LVL TIME	3LVL TIME
R522*0	01.0	01.5
R522B0	01.0	01.5
R522E0	01.0	01.5
R723*0	01.5	02.3
R723A0	01.2	01.8
R723A1	01.2	01.8
R723B0	00.9	01.4
R723B1	01.2	01.8
R72500	02.0	03.0
R731*0	01.7	02.0
R731B0	01.0	02.0
R731C0	01.5	02.0
R731DC	01.3	02.0
R731E0	01.0	02.0
R731G1	01.2	02.4
R74B*0	01.2	02.0
R74BA0	02.0	02.0
R74BB0	02.0	02.5
R74BM0	00.8	01.2
R74BN0	03.0	03.5
R74C*0	00.6	01.0
R74CA0	01.9	01.9
R74CB0	01.9	03.5
R74CC0	01.4	02.5
R74D*0	01.4	02.0
R74D*1	01.0	02.0
R74DA0	00.5	01.5
R74DB0	01.8	03.5
R74DC0	01.4	02.0
R74E00	01.8	03.5
R74E01	02.6	03.6
R74300	01.0	02.0
R748*0	01.0	02.0
R74810	01.3	04.0
R74820	01.4	02.0
R74830	02.0	02.5
R74840	03.0	05.0
R75E00	04.8	05.6
R75E01	06.0	12.0
R751C0	01.0	02.0
R751DC	01.4	02.8
R75600	01.4	02.8
R75600	01.6	03.2
R75800	01.0	02.0
R75900	02.0	04.0
R76E*1	01.3	02.6
R76E*2	01.6	03.2
R76E*3	01.5	03.0
R76EA0	03.0	06.0
R76EB0	03.0	06.0
R76EC0	02.0	04.0
R76ED0	03.0	06.0
R76F*0	01.5	03.0
R76FA0	02.1	04.2
R76G00	01.5	03.0
R77J*0	01.5	02.3
R77J2K	01.4	02.1
R77K2A	01.7	02.6
R77X*0	01.8	02.7
R77X6D	00.7	01.1
R91200	01.3	02.0
R93200	01.3	02.0
R97900	00.7	01.1
V111A0	00.3	00.6
V23000	08.0	16.0
V75600	00.6	01.2
V76G00	00.5	01.0
Y2AM74	00.2	00.3
Y2AM75	00.5	00.8
Y23M03	01.3	07.0
Y23M04	01.2	02.8
Y23M05	03.9	05.9
Y23R00	12.0	18.0
Y23R01	36.0	40.0
Y23R02	02.9	04.5
Y4AM90	00.1	00.2
Y4AM91	00.4	00.6
Y4AM92	00.6	00.9
Y4AM93	00.8	01.2
Y4AM94	00.1	00.2
Y4AM95	01.3	02.0
Y4AM96	01.0	01.5
Y4AM97	00.1	00.2
Y4AM98	00.2	00.3
Y4AM99	00.3	00.5

APPENDIX D

Pilot Opinions

Opinion Survey of Aircraft Pilots

Pertaining to Maintenance Skill Level Changes

There is some consideration being given to reducing the average aircraft maintenance skill levels at operational units from the current average 5 level to the minimum possible to perform the tasks required in both scheduled and unscheduled maintenance.

In an attempt to analyze the impact this skill level change may have upon mission accomplishment, I am interested in your opinion as a pilot who will be flying the affected aircraft as to what impact this skill level change will produce. Therefore I have developed the attached questionaire to aid in expressing your opinion. Please feel free to add any comments you may have pertaining to the subject. You need not identify yourself unless you wish. The information gained will be used only for the purpose stated. Please return the completed survey to Captain Larry Howell, ASD/YYEE.

1. Would a reduction in military aircraft maintenance skill level affect your decision to stay in service and fly military aircraft? If so, how?

2. Would you anticipate more sortie aborts or cancellations due to the skill level reduction? If so, can you estimate the percent abort increase and identify what aircraft type might be most effected?

3. Would you anticipate an increase in the number of quality control reworks if the proposed skill level reduction should become reality? If so, how much?

4. Do you believe there would be an increase in the number of aircraft accidents due to such a skill level change? If so, how much?

5. The proposed skill level reduction may result from shorter enlistments or a rapid increase in military manpower build up. If you see this skill level decrease as hazardous or detrimental, can you suggest an alternative plan or a method to obtain and maintain the required skilled personnel?

6. What other comments do you have pertaining to maintenance skill levels?

RESULTS OF OPINION SURVEY AS OF 11 MAY 1979

1. Would a reduction in military aircraft maintenance skill level affect your decision to stay in service and fly military aircraft? If so, how?

No - 17

Yes - 2, maintenance is not good enough now

2. Would you anticipate more sortie aborts or cancellations due to the skill level reduction?

No - 2

Yes - 17

If so, can you estimate the percent abort increase and identify what aircraft type might be most effected?

50% - 12	Fighting - 17	Some named - 2
25% - 3	Bombing - 8	
20% - 1	Cargo - 2	
5% - 1		

3. Would you anticipate an increase in the number of quality control reworks if the proposed skill level reduction should become reality? If so, how much?

No - 0	10% - 1
Yes - 19	25% - 5
	50% - 10
	100% - 2
	500% - 1

4. Do you believe there would be an increase in the number of aircraft accidents due to such a skill level change? If so, how much?

No - 15	50% - 1
Yes - 4	100% - 1

5. The proposed skill level reduction may result from shortened enlistments or a rapid increase in military man-power build up. If you see this skill level decrease as hazardous or detrimental, can you suggest an alternative plan or a method to obtain and maintain the required skilled personnel?

No - 6

More pay for enlisted - 1

Proficiency pay - 10

Commitments for training - 1

6. What other comments do you have pertaining to maintenance skill levels?

Hire civilian maintenance

Contract maintenance

Design simple aircraft